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12

Cognition and Instruction: Enriching the Laboratory School Experience of Children, Teachers, Parents, and Undergraduates

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The primary focus of this symposium volume is advances in the understanding of teaching and learning that have developed because of the increasingly reciprocal relationships between psychology and education, between research and practice, and between laboratory and classroom learning contexts. The beneficial synergy between theory, research, and practice has been exemplified in each chapter by fruitful researchers who have contributed significantly to our understanding of cognition and instruction.

The purpose of this chapter is to describe the ways that such research can impact an entire school when the Director of the school, trained as a cognitive psychologist, assumes the responsibility for fostering the development of every child in the school, in every domain, every day of the school year, across, in this case, a 3-year period of preschool and kindergarten. With that as a foundation, I also highlight the ways that the same cognitively based approach has been applied across all aspects of the school's mission,[1] including the professional development of teachers, the interactions with parents of the children in the school, and the undergraduate academic opportunities. Despite the daunting size and incredible complexity of this task, I consistently conclude that the educational experience of each constituent is enriched by the contributions of this field. By sharing these laboratory school experiences, I hope to encourage the continued progress of cognition and instruction research, such as that represented by the other chapters in this volume, and to suggest areas for future expansion of the field in theory, research, and practical impact.

THE CENTRAL PROCESS: EXPLICIT GOALS DRIVING INSTRUCTION AND ASSESSMENT DESIGN

My thinking about the link between cognition and instruction was heavily influenced by one point that Jim Greeno (1976) raised at the original Cognition and Instruction symposium in 1974; that is, his notion of using cognitive objectives as opposed to the traditional behavioral ones. He suggested that

> ... the explicit statement of instructional objectives based on psychological theory should have beneficial effects both in design of instruction and assessment of student achievement. The reason in simple: we can generally do a better job of accomplishing something and determining how well we've accomplished it when we have a better understanding of what it is we are trying to accomplish. (p. 123)

For the past 17 years, I have used the three-fold process suggested by this quote to direct my own research, as well as my consulting on others' educational and research designs (see Table 12.1). I begin with a formal domain analysis specifying the declarative, procedural, and metacognitive knowledge that a learner at a given developmental level and with a typical

[1]The Children's School is the laboratory school for Carnegie Mellon's Psychology Department. Its goals and responsibilities include (1) development and management of laboratories for research in developmental psychology, (2) training of undergraduate and graduate students in child development theory and research, (3) implementation of a model half-day preschool and full-day kindergarten program for children ages 3–6, (4) provision of resources to parents, (5) provision of resources to the community of early childhood educators, and (6) training of students earning teaching certificates (in collaboration with other local colleges and universities).

TABLE 12.1
GOALS → PROGRAM → ASSESSMENT Approach

Goals:	Detailed Task Analysis Considering Developmental Level Considering Knowledge Base Considering Available Time
Program:	Explicit Focus on Target Consistent with Cognitive Principles
Assessment:	Cognitive Assessments of Process Covering the Full Target

knowledge base could reasonably be expected to acquire in the designated period of time. I then design instructional interventions to explicitly target the identified goals in ways that are consistent with well-established cognitive principles and develop cognitive assessments of learning that cover the full range of the targeted skills. The arrows in the title of Table 12.1 connote the essential alignment of the goals, program, and assessment rather than indicating a rigid sequence of design. In practice, the consideration of possible assessments helps sharpen the goal specifications and narrow the program options, and program constraints impact both goals and assessment.

My first attempt to apply this approach began with a limited but tractable set of debugging skills (Carver & Klahr, 1986; Klahr & Carver, 1988), one of the powerful ideas that many educators believed elementary school children would discover via experience with well-designed programming languages. First, I specified a model of basic LOGO debugging skills, including key knowledge and strategies necessary for identifying the likely type and location of a bug before beginning to search the program code. I found that students with extensive but unstructured LOGO experience did not build a useful knowledge base of bug types or discover these effective debugging skills. I then developed a 30-minute lesson to teach the search narrowing skills explicitly and found that elementary students were able to utilize the strategies with minimal teacher support. In several studies, I then demonstrated that students applied the target debugging skills on program debugging tasks, transferred them to noncomputer debugging tasks (specifically, finding the mistake in a written set of directions), and maintained their new level of performance after a semester's delay (Carver, 1988). In other words, short-term explicit instruction can promote significant learning, transfer, and retention, at least for this well-defined domain in a small class context, with me as the teacher, using assessments that are carefully designed to have goal structures isomorphic to the instruction.

In an attempt to work more closely with teachers on a topic of broader educational significance in a more realistic school setting, I studied the "research and communication skills" necessary for urban students doing typical middle school reports. In a 4-year series of studies that involved major redesign of middle school curriculum,[2] my students and I found that by identifying the goal structure and key strategies involved in the process, we were able to design explicit instruction that was successful in promoting middle school students' use of the targeted process (Carver, 1995, in press). For example, in one study that I did with Myunghee Kang (Carver, in press; Carver & Kang, 1999), we focused on the process of organizing notes into a coherent structure that could be represented in HyperCard. Kang developed instruction that focused the students on intentionally completing each step in the organization process and evaluating their own and other students' stacks for their organizational quality. Using a split-class design, she showed that the half of each class that got the focused instruction based on her model improved more from pretest to posttest than did the other half of the students on three different assessments, an interview conducted during their own process of organizing material for a class project, an analysis of the organizational quality of the stack they produced, and a written test with questions about how they conduct research projects. Once again, the key finding was that an explicit link between goals, program design, and assessment provides a powerful means of enhancing learning. However, we found that it was much more difficult and complicated to use this approach in a real school context, for an extended period of time, while targeting a broader set of skills. Also, although the collaborative approach between researchers and teachers proved useful in many ways, the project was plagued with high teacher mobility rates and an inconsistent commitment of the public school system. This situation caused frequent frustrations, ones that are commonly experienced by many of the researchers who contributed to this volume.

Thus, when presented with the opportunity to gain more control of the administrative aspects of my school site by becoming a Director, I decided to shift career tracks to head a psychology department laboratory school. The challenge is, of course, that now I am responsible for the education of

[2]This research was supported by grants from the James S. McDonnell Foundation's Cognitive Studies in Educational Practice Program, by Apple Computer, Inc.'s Crossroads Program, and by a subcontract from the Center for Technology in Education.

children, teachers, parents, and undergraduates, not to mention the public relations, facilities, and other school issues that are beyond the scope of this chapter. The relevant question for this volume is: To what extent can I use principles derived from cognitive theories and research, together with experience from educational practice, to set appropriate goals for development, to design an instructional program that will encourage growth, and to assess each individual's progress? Table 12.2 shows how I summarize the approach in teacher and/or administrator training contexts.

Integrating cognition and instruction across an entire school required me to simplify the approach that I had used in my earlier research. I needed to find a practically useful level of application for the cognitive principles and research strategies that shaped my work on debugging and on research and communication. Jim Minstrell's description of continually switching hats from teacher to researcher while adapting his goals, instructional approaches, and even assessments "online" (chap. 4) parallels my situation. As with most new problem-solving contexts, I initially applied "weak methods," general heuristics based on well-established cognitive principles, and then developed stronger, more context-specific methods via experience and refinement cycles. We have been the most thorough and made the most progress in using clear goals to design the children's program and assessments, so I present that first. Then, I briefly discuss the ways that the same approach applies to the teachers, parents, and undergraduates, even though we have spent less formal development time on those aspects.

TABLE 12.2
The G → P → A Approach as Presented in Training

Children's School *Goals → Program → Assessment (GPA) Approach*
• Specify developmentally appropriate learning objectives (GOALS) re: the Whole Child and the specific population served. • Use the goals as a systematic framework for focusing PROGRAM and ASSESSMENT design. Structure the Early Childhood Program to Foster Development • Teaching Strategies • Classroom Routines & Transitions • Curriculum Content with Developmentally Appropriate Activities • Learning Environment Focus Assessment on the Goals • Teacher Observations • Teacher Documentation • Parent Conferences

GOAL-DRIVEN DESIGNS FOR YOUNG CHILDREN

Specifying Goals

Given the wide range of social, cognitive, and physical development goals for young children, doing a full task analysis of each subgoal was not practical. We used the strategy of starting with a global level analysis and then made continual refinements to get more specific, particularly for areas that required more program input for their development. My teachers and I started with specifying and prioritizing the general areas of development for which we would set goals (see Table 12.3). At an early childhood level, fostering "Self-Esteem and Independence" and "Interaction and Cooperation" should get top priority because students entering elementary school without those skills have the greatest difficulty succeeding. The more traditionally cognitive domains of development were also strongly emphasized. We used the terms "Communication" and "Discovery and Exploration" to focus explicitly on the cognitive foundations for academics rather than on subject areas, like language arts, science, and math. "Physical Capabilities" was included but with a low priority because both small and large motor development progresses without much intervention, assuming that the child has ample opportunity for productive movement. Finally, "Creativity" was added because we wanted

TABLE 12.3
Learning Goals Underlying Program and Assessment

Children's School Basic Learning Goals
1. **Self-Esteem & Independence**—encouraging each child's pride in individual characteristics, families, experiences, and accomplishments and each child's responsibility for personal care, actions, and words.
2. **Interaction & Cooperation**—promoting children's social skills for diverse adult and peer relations, including listening, turn taking, following directions, rules and routines, group participation, care for shared materials, and conflict resolution.
3. **Communication**—facilitating comprehension and expression skills beginning with oral and progressing to written language.
4. **Discovery & Exploration**—fostering a positive attitude toward learning through questioning, observing, and experimenting with varied materials related to diverse themes.
5. **Physical Capabilities**—giving children opportunities to use their growing bodies to develop small and large motor skills and coordination.
6. **Creativity**—cultivating each child's ability to express ideas and emotions through art, music, movement, and drama.

to promote children's ability to express themselves and their ideas in a variety of ways.

Specifying categories such as these is important for establishing a consistent framework for the school (including the education of teachers, parents, and undergraduates), but this level of description is not otherwise useful for instruction and assessment design. Our staff works from goal specifications that we developed at one level deeper than those in Table 12.3 and that indicate the anticipated progression from age 3 to 5. We developed these more detailed specifications by collecting educational goal statements for preschoolers from around the country and then using the teachers' experience and my knowledge of developmental research to refine them. Typically, the developmental literature led to added breadth and depth in the cognitive areas, and it also helped ensure that we were following natural developmental sequences, like those that Kalchman, Moss, and Case described for mathematics (chap. 1).

To exemplify the level of task analysis we used, Appendix A includes the full outline and parts of our specification for the domains of Communication and of Discovery and Exploration.[3] For the Communication domain, we focus on speaking, literature/reading, and writing, each of which is divided into subcategories. For the Discovery and Exploration domain, we focus on foundations for scientific and mathematical thinking. Each domain includes goals for generalizable attitudes, concepts, and skills. Bob Siegler raised the question of how to inculcate the "habit of mind" to pursue meaning (chap. 6). At the Children's School, we make "approaches to learning" an explicit goal for young children and then design program routines, teaching strategies, and curriculum activities to foster such development. At this level of education, we are not particularly concerned with children developing a specific, well-defined body of conceptual knowledge from social studies or science, but we do vary our units to expose children to a range of topics for study. For each thematic unit, we identify the basic concepts related to the topic, introduce them in a variety of ways, and reinforce them via diverse activities. Because the units vary from year to year and the conceptual content for each is extensive, only key concepts that are relevant in many units are listed as general goals. For example, the goals for Discovery and Exploration include basic number, space, and measurement concepts (see the outline in Appendix A). Our goal specification does, however, include an extensive

[3]The full specification for all six domains listed in Table 12.3 is available by contacting Dr. Sharon M. Carver at the Children's School, Carnegie Mellon University, Pittsburgh, PA 15213.

list of skills because most of the skills that we emphasize in all six domains are applicable across topics of study. Taken together, the general approaches to learning, basic concepts, and widely applicable skills that we have specified represent our understanding of the early childhood development that our program is designed to support and foster.

Designing a Model Program

Having clear goals for the children's development guides our program design and refinement efforts, but where does cognitive theory and research fit? A Piagetian might stress the importance of creating an environment in which preoperational children can engage in active learning, continually assimilating new experiences and accommodating schemata until they eventually reorganize their cognitive structures to reach a new level of concrete reasoning (Miller, 1993). A Vygotskian would place more emphasis on the social interactions involved in the learning process by focusing on ways an adult or more skilled peer could provide scaffolding so that the child is able to practice and eventually master tasks at the higher end of her zone of proximal development (Miller, 1993). Teachers are, in fact, drawn to these approaches because they are highly general "rules of thumb" that can be used to label, describe, or justify many of the strategies that excellent teachers use naturally.

Applying the more detailed principles from the field of Cognition and Instruction offers a clearer vocabulary for discussing the predicted effects of particular program features, a level of description one level deeper than the approaches I just mentioned (e.g., Klahr, Chen, & Toth distinguish between domain-general and domain-specific knowledge, chap. 3), and a more systematic focus on the process of change. Together, these benefits enable us to move beyond the artificial constraints imposed by stage boundaries to consider the specific conditions under which particular children progress toward each goal most effectively. They also specify a wide variety of scaffolding strategies so teachers can purposefully choose among them in different contexts. As Palincsar and Magnusson suggested in chapter 5, researchers need to focus on a smaller grain size in their analyses of teaching and learning to specify why certain approaches, like their use of the scientist's notebook to model scientific inquiry processes, have particular effects.

Lists of such "key principles" are widely available, typically in texts with titles such as *Cognitive Psychology for Teachers* (Glover, Ronning, & Bruning, 1990) or *Cognitive Classroom Learning* (Phye & Andre, 1986), and each researcher in the field, at least implicitly, has a favorite set. In this chapter, I describe the top five metaprinciples that we use to shape our early childhood program. Each of these is typically part of expert teachers' repertoire of strategies, but I have found that making them explicit during design discussions increases the likelihood that they are consistently and effectively taught and applied.

Metaprinciple 1: Build on Prior Knowledge. An extensive body of literature from cognitive and developmental psychology indicates the importance of activating prior knowledge in order to get effective storage and, ultimately, retrieval of new knowledge (Anderson, 1983), as well as the impact of a learner's correct and incorrect models of a domain (Siegler, 1998). In addition, learners typically demonstrate the most advanced processing in familiar contexts and show the greatest attention span and memory in situations for which they have developed a high level of automaticity of their procedures (Chi, 1981).

At the Children's School, we begin our instructional design process with an understanding of the foundations with which individuals enter our learning context. Based on both the developmental research literature and practical teaching experience, we expect a typical range of information-processing capacity, knowledge, strategies, and metacognitive skill in social, cognitive, and physical development based on the children's ages and background. With this in mind, we formulate what we believe to be developmentally appropriate daily schedules, classroom routines, and physical arrangements of the learning environment for each group of students. To offer a simple example, the size and spacing of the furniture in the classrooms changes in accordance with the children's physical stature and with the increasing control of their bodies. Similarly, the classroom routines become more elaborate and rely more heavily on the children taking responsibility as their level of independence for self-care and cognitive capacity for following multistep procedures improves.

The Children's School curriculum is designed to build on children's prior knowledge and to foster growth toward mastery of the goals we have specified. We develop thematic units that invite children to explore specific topics in depth while challenging them in each of the six domains. Our teachers explicitly take prior knowledge into account in planning the units by specifying the topic-related concepts that they anticipate the group already possesses (including possible "preconceptions," as Minstrell calls them in chap. 4) and then identifying key concepts that they intend to help the children develop. When designing a unit, the teachers use their knowledge of the unit's timing within the year and sequence relative to other units to specify which aspects of each goal domain should be emphasized. They list theme-related activities designed to foster development within each domain. Appendix B includes excerpts from the study of "Ponds" that was in progress at the Children's School during the symposium.

Evidence for the centrality of this prior knowledge principle exists within this very volume, in the frequency with which it drove the researchers' task analyses and intervention designs. The application of Metaprinciple #1 was clearly evident in the developmental sequence of layers in the conceptual structure for number, the explicit links between instruction and the students' existing knowledge of percents, and the "walk-a-thon" problems (Kalchman, Moss, & Case, chap. 1). Palincsar and Magnusson's explicit links between second-hand investigations and the students' own experiments (chap. 5), rather than the commonly used reverse order, exemplifies instructional design based on maximizing prior knowledge effects. Minstrell's specification of knowledge "facets" and choice of instructional prompts based on a diagnosis of a student's current set of facets (chap. 4) is also a direct application of Metaprinciple #1. Similarly, Lehrer, Schauble, Strom and Pligge's instruction built carefully on students' "intuitive theories," and new concepts were "anchored" in concepts built during the prior year's instruction (chap. 2). At a more philosophical level, their whole project stemmed from a claim about the importance of prior knowledge, that is, that mathematizing ideas creates a firm foundation for understanding science.

Metaprinciple 2: Make Thinking Explicit. Research in cognitive psychology has documented the value of explicit communication for explaining properties of the task (Carver & Klahr, 1986), directing learners' attention to key features, which in turn aids encoding, clarifying declarative, procedural, and, especially, metacognitive components of the learning task (Siegler, 1998), highlighting distinctions between similar concepts and procedures (Anderson, 1983), and providing effective feedback (Anderson, Corbett, Koedinger, & Pelletier, 1995). Developing specific prompts for the key steps in a cognitive activity, whether they are verbally given by a teacher, embedded in a visual model (Carver, 1995), or supported by an intelligent tutor (Anderson et al., 1995), both strengthen and fine tune the thinking process.

Klahr, Chen, and Toth's primary manipulation (chap. 3) directly tested this explicitness principle and showed that combining clear probes with

training yielded the best performance. Other researchers' work demonstrated the important point that explicitness does not necessarily imply direct "telling." Lehrer, Schauble, Strom, and Pligge used "inscriptions" to make thinking explicit (chap. 2); Palincsar amd Magnusson invented the "scientist's notebook" (chap. 5); and Minstrell fashioned a set of queries posed by the "Diagnoser" in response to student answers that reveal "preconceptions" (chap. 4).

At the Children's School, having thematic units developed with specific focus on the key concepts and developmental goals is an important first step in making thinking explicit (Appendix B). The teachers, themselves, are clearer about what they are trying to teach and they are more likely to stress key concepts and balance their emphasis on all six domains of development. In addition, the teachers use many verbal and gestural strategies to direct the children's attention to the central elements of a concept or task. In one recent book reading session on the solar system, a preschool teacher used (a) increased volume and enunciation, (b) verbal repetition, (c) representational gesture with one finger, and even (d) full-body enactment to highlight the difference between rotation of the earth and revolution around the sun. As the children ask questions and offer examples during discussions, the teachers explicitly shape their understanding via direct instruction, posing questions, and encouraging comparison and contrast.

One striking example that integrates both of the first two metaprinciples is our approach to fostering conflict resolution in young children. Initially, the teacher intervenes in the process to explicitly model strategies for identifying the problem from both children's point of view, proposing solutions, agreeing on one, and then implementing it. As the children become familiar with the process, the teacher becomes a coach who prompts them for each step of the process as necessary, until the children become comfortable doing it independently. Recently, in the context of working with our youngest and least skilled children on conflict resolution, we began to discuss the cognitive capacity constraints on the process. We found that the demands of formulating sentences in an emotionally charged context were too high for the youngest children, so we began offering sentence templates and using gestures instead. Similar approaches have been utilized effectively at the Child Development Center at U.C. Davis (Linda Acredolo, personal communication, 11/5/98), and the potential for gestural evidence of cognitive states preceding verbal evidence has been documented in the laboratory (Alibali & Goldin-Meadow, 1993).

Analyzing two individual cases in which children had extreme difficulty with conflict resolution revealed contrasting starting points for intervention and differential focus for explicitness. In one case, the child entered the program viewing verbal and physical aggression as a game of control, so the teachers supplemented the modeling described earlier with explicit prompting to consider other children's perspectives and to notice the positive outcomes of nonaggressive interactions. Another child with similar aggressive tendencies had proprioceptive difficulties monitoring and controlling his own body, which then required us to focus our explicit discussion and modeling on the physical aspects of conflict resolution, such as increasing the amount of space between the children in conflict and the amount of physical support the teacher used.

Metaprinciple 3: Emphasize Links. In Siegler's discussion of the first five chapters in this volume (chap. 6), he extracted this metaprinciple as a common thread, phrased as "the meaning is in the links." Minstrell's example of comparing and contrasting the forces acting on varied supports for a book (chap. 4), Kalchman, Moss, and Case's development of manipulatives to embody mathematics concepts (chap. 1), and Lehrer, Schauble, Strom, and Pligge's multiple representations for ratios (chap. 2) all exemplify instructional designs based on extensive research documenting the advantages of cognitive organization and elaborative processing (Siegler, 1998). Using advanced organizers, providing multiple representations of concepts, generating examples and explanations, and otherwise elaboratively processing information contribute to the development of better integrated and more complex knowledge structures (Glover, Ronning, & Bruning, 1990). These connections, in turn, improve retrieval, help fill gaps in recall, and generally improve one's comprehension.

During individual lessons within a unit, our teachers use a variety of strategies for encouraging the development of a well-integrated knowledge base. They routinely combine visual and verbal representations, invite students to share their experiences related to a given lesson, and intentionally ask children to recall aspects of prior related lessons. To represent specific connections, they often draw concept webs for a given topic during their discussions with the children in their group. Typically, the web is started as a means of activating prior knowledge during the introduction of a topic, and then ideas are added during subsequent sessions in which nonfiction books are read, artifacts are explored, experiments conducted, and so forth. Even for nonreaders, this webbing strategy explicitly emphasizes the relationship between concepts and encourages the children to begin intentionally connecting ideas.

Emphasizing one theme for an extended time period, such as the 2 to 3 weeks of our units, allows the children to explore multiple aspects of a concept. For example, we began the "Ponds" unit by studying the water, progressed to exploring the plant life in and around the water, and then continued with the animal life. The children made repeated trips to the pond near campus, each time reinforcing and extending their concepts, making connections between what they discussed at school and what they experienced at the pond.

Although our teachers continually refine their use of strategies such as webbing and extended thematic units, studying their specific impact on children's developing concepts is an untapped research area in early childhood development. As we explore the effectiveness of modifications such as adding graphic images to webs, we are also planning to develop research procedures that can be used within our program while maintaining experimental control.

Metaprinciple 4: Provide Practice Opportunities. The necessity of repetition in varied contexts for the development of proficient and efficient skills has been well documented (Anderson, 1983). Basic findings of frequency and distributed practice effects are easily applied in educational contexts. We discuss the importance of practicing routines to develop strong scripts, and repetition of existing skills to develop the automaticity that frees capacity for more advanced tasks or combination of skills. We balance that with the importance of providing a wide variety of contexts for knowledge and skill application to heighten the distinctiveness of both concepts and strategies, as well as improve the generality of their application (Glover, Ronning, & Bruning, 1990). In addition to the standard cognitive literature, specific recommendations for sequencing practice opportunities are discussed in the cognitive apprenticeship literature (Collins, Brown, & Newman, 1989; Collins, Hawkins, & Carver, 1991).

The consistent repetition of the Children's School daily and weekly routines, as well as the consistent expectations for behavior, increases the strength of their memory and ease of retrievability, which, in turn, sets the stage for the children's comfort with and independence in our learning environment. Offering opportunities for repeated practice of foundational skills encourages children to work toward mastery, which also increases self-esteem. Kalchman, Moss, and Case's high ratio of problems per representation (chap. 1) focuses on the repetition aspect of the practice principle and also emphasizes the ways that cognitive gains underlie social and motivational improvements.

Within a thematic unit, children have varied opportunities to acquire, strengthen, and refine their concepts via experimentation, stories, dramatic play, art, games, computer activities, and so forth. We also attempt to develop a conceptual progression across units that reinforces and extends children's concepts. For example, we recently planned a sequence for the fall that involves studying ourselves and our families, where we live (country and city, buildings, transportation, and community helpers), what we eat (food, farms, grocery stores, and restaurants), and what we wear (clothing, shoes, hats, work clothes, dress clothes). In the winter, we will then study China, comparing and contrasting all of the same aspects. In addition to supporting conceptual development, our thematic units actually serve as varied contexts for growth in each of the six domains. Within each unit, we purposely provide activities that foster increasingly diverse and complex uses of the skills in each of our six developmental domains. This distributed practice in varied and increasingly challenging contexts promotes skill acquisition that is impressively generalizable. Similar applications of Metaprinciple #4 are clearly evident in Palincsar and Magnusson's "cycles of inquiry" (chap. 5), Minstrell's combination of work with the Diagnoser, labs, and class discussions (chap. 4), and Reiser, Tabak, Sandoval, Smith, Steinmuller, and Leone's integrated design for technology-infused curricula (chap. 9).

Metaprinciple 5: Expect Individual Variability. Often times, cognitive and developmental psychologists focus on establishing characteristics of cognitive processing, developmental progressions, and the effects of experience at a group level. As I have already discussed, these findings are clearly useful for establishing reasonable developmental goals and metaprinciples of design for educational contexts. At the same time, researchers who analyze their data at an individual level, such as Klahr, Chen, and Toth's analysis of different learning patterns for individual students (chap. 3), often discover dramatic contrasts in the learning process. Similarly, at the classroom level, the impact of individual variability is often a significant factor, and our success in responding to the full range typically determines our overall effectiveness.

In our preschool, we divide our preschool children into groups with only a 6-month range of ages, which limits the developmental range more than most schools and allows our teachers to focus their lessons on a narrower range. Nonetheless, we find a wide variability in developmental levels that is exaggerated by divergent background experiences, even for our young 3-year-olds, and by individual differences such as those Gardner (1993) might characterize as intelligence profiles, or others might describe

as "learning styles" (Tobias, 1994). In addition, individual variability in home situations and the presence of developmental disabilities, however subtle, need to be included in the instructional planning process. For that reason, we also incorporate periods of time when children interact across groups, both indoors and outdoors. In these contexts, children are more able to interact with children of similar interests and abilities, independent of age grouping.

This principle highlights one limitation of applying the theories, methods, and findings of research in the field of cognition and instruction, and often makes me wish I had degrees in medicine, counseling, and special education. The key is that we need to focus on the integration of social, cognitive, and physical domains within one child and realize that what happens during the 18 to 20 hours per day the child spends outside of school impacts what happens in school. We need to evaluate the individual combination of developmental, experiential, and potential ability and disability factors that impact a child's progress so that we can plan individualized strategies for fostering development.

For example, many kindergartners start the year with poorly developed fine motor skills, partly because of developmental constraints and partly because of the types of experience available in the previous years both in and out of school. Typically, such skill limitations cause no problem because physical maturation in the 5th and 6th years and the fine motor activities in our kindergarten program together yield impressive progress for almost all children. One child, however, did not progress like the others, despite strong cognitive skills. The fact that he could not dress himself, open his lunchbox, and ride a tricycle started impacting his self-confidence and his social interactions. Increasing frustrations in both social and physical domains yielded further isolation and emotional breakdowns, which eventually started impacting the cognitive progress as well. Obviously, inadequacies in any of these domains have mutual influence in a negative direction here. Thus, we began to explore factors beyond maturation and experience as the primary cause of the problem. To make a long story short, we relied on counseling skills in working with the parents to encourage developmental screening and neurological diagnostics, then consulted with medical personnel to eventually reach a diagnosis of dyspraxia (poor motor planning), and finally integrated some basic special education strategies to identify ways to use the child's cognitive strengths to explicitly coach himself in motor planning.

Discovering and dealing with such individual variability essentially means that we must utilize a case study approach to determine the key goals for emphasis and effective instructional strategies relative to each child's specific foundations. That requires an acceptance of nonstandard instruction. Although designing the instructional program in advance is important, as described earlier, our success with whole, individual children depends largely on the teacher's ability to adapt her program to each individual student based on her concurrent assessment of the child's understanding, progress, attitude, and so forth. In addition, unlike a research project that targets one specific set of skills per instructional program, in a real classroom, multiple goals are simultaneously being targeted. In many cases, a teacher will use one activity to strengthen different skills in individual children. For example, a teacher might play the familiar game of Chutes & Ladders with three preschoolers, emphasizing the number patterns with Nina, who already taught herself to read in both English and Russian, focusing on politely taking turns and encouraging each other with Mary, who was diagnosed with autism, and physically directing Justin's hand to move appropriately from square to square to help refine his proprioceptive control of motor direction and force.

Assessing Progress

The online adaptation that characterizes our instructional approach is, in a sense, our primary method of assessment. As such, it involves the same cognitive principles of (1) identifying a child's prior knowledge, (2) following her thought processes as she communicates them via actions and words, (3) noting the connections she makes between ideas, (4) tracking her applications and improvements in various contexts of practice, and (5) consciously recording individual factors of maturation, environment, and abilities or disabilities.

We use our six domains of development to structure our assessment process. The product is a conference form that summarizes a child's progress in each area via a brief checklist and a paragraph of explanation (see Appendix C for examples related to Communication and Discovery & Exploration). The teacher talks with the child's parents about each aspect of development to provide additional explanation, detail, and often strategies for improvement. Having consistent categories and types of items within them helped us to get diverse teachers to talk about the same aspects of development with parents across the 3 years of our program.

The teachers develop these summaries based on longitudinal observation of the child in the natural school context. They record anecdotes about the child's interaction with others, response to activities, and so forth. They save products of the children's exploration where possible or

take photos of others, such as block structures built. Our collection of varied evidence within the classroom context is similar to Minstrell's use of discussion comments, test performance, lab activities, and other written work as the basis for assessing his students (chap. 4).

For domains where classroom observation is impractical because of the number of children or the complexity of the target skills, we have developed some structured, individual assessments that are conducted by a research assistant who then communicates the results to the child's teacher in writing. The sessions are also videotaped so that the teacher can watch them if necessary. For example, we developed an assessment this semester that tapped a variety of communication skills within a single session (see Appendix D).

Although the level of detail possible with such structured assessments could be very useful, it is not practical to assess every detail of every subgoal for all six domains. For that reason, we reserve the most detailed analysis and documentation for cases of developmental difficulty or significant delay, such as those previously described as struggling with aggression or dyspraxia. Challenging situations in both instruction and assessment arenas are also the ones where we analyze our own applications of the cognitive metaprinciples most closely, because that is where we stand to benefit most from the time and effort required to do the analysis. As the next part indicates, such analyses are central to the alignment of goals, program, and assessment for the adult learners in the laboratory school.

GOAL-DRIVEN DESIGNS FOR ADULT LEARNERS

Although we have not described our approach with teachers, parents, or undergraduates in as much detail as we have for the children, the essential process of basing program design and assessment on clear specifications of developmental goals and on strong cognitive principles is the same. From the start, we have a simpler case because we can typically assume the fully developed adult cognitive system at the outset. Also, our responsibility is primarily for fostering growth in the cognitive domain, although each individual's interaction skills, relational context, health status, and so forth, often have a major impact on the outcomes.

At a global level, my goal for all of the adults in the laboratory school context is to understand and to be able to utilize information from theory,

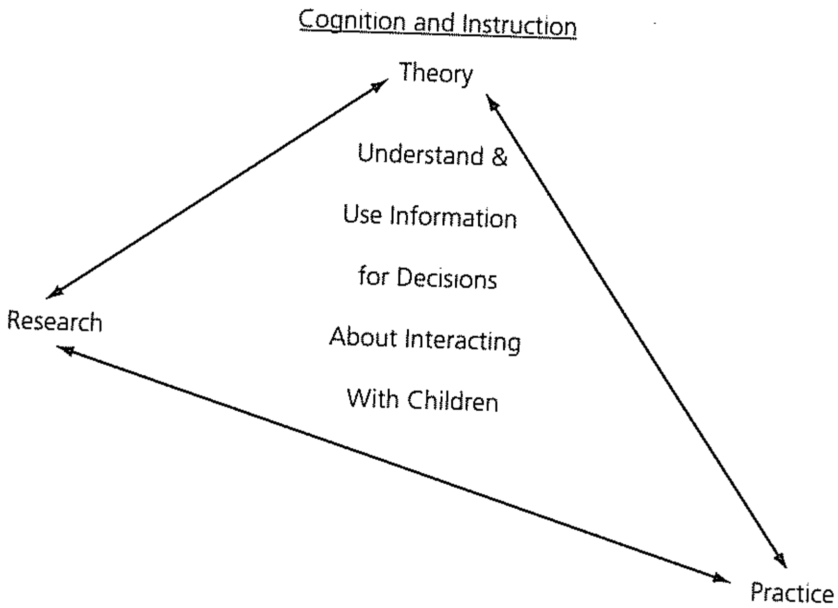

FIG. 12.1. Contributions from theory, research, and practice.

research, and practice to make sound decisions about the ways that they interact with young children. The differences in approach for adult learners in the laboratory school stems primarily from the differing amounts of background they have with each part of the theory, research, and practice triangle (Fig. 12.1).

Staff Development

Teachers at the laboratory school start with a strong foundation in the practice part of the triangle—excellent interaction styles, prior knowledge of which activities work and which do not, and lots of experience adapting their approaches to a wide variety of children. All have some coursework in child development and most are active readers of early childhood journals, which occasionally mention psychology theories or research findings while describing effective educational methods. Despite teaching in CMU's laboratory school, none of the teachers on the staff when I arrived had formal knowledge of information-processing theories, even those that were developed via research in their own school, and I have never been able to hire a teacher who has already had such training.

Given that my goal is to strengthen and better integrate each part of the triangle, what "program" can I provide for teachers and how can I assess their progress? As a director, I work with the teachers through the formal professional development opportunities that I offer, the informal consulting on program, students, and so forth that I provide, and the collaborative work I do with teachers when we become the teachers of teachers, parents, and undergraduates. Progress is most directly evident in the teachers' dialogue with me and each other and in their written work, but it can also be inferred by observing them in the classroom. Most of my assessment involves ongoing and informal evaluations that impact my staff development program; although I do have a more formal, annual evaluation meeting with each staff person to discuss their progress and the next steps in each of seven categories.[4]

Because practical knowledge was the clearest strength of my staff, I began 6 years ago by using professional development time to explicitly discuss the teachers' goals for their students, to agree on a consistent vocabulary for goal categories, and to establish an appropriate progression of expectations for the 3 years of our program, based on the foundations with which children typically enter our program and the common developmental changes they may experience. We then altered our assessment process and conference forms to align with the six goal categories, so that teachers would discuss the same aspects of development in each of their reports each year. Once we were clear about our goals and the aspects of each that we would be assessing, the next step was to plan our program to foster each aspect of development. What we learned was that having the goals framework helped us to determine whether our program was providing a well-balanced set of learning experiences, to choose among the many possible activities, and to intentionally focus activities on the areas in which a particular student or group of students was weak. This process has made our thinking about early childhood education explicit, and the goal framework has helped organize the links we form as we read new articles, visit other programs, and integrate new methods and materials into our program.

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[4]Teacher assessment categories include Interactions with Children, Program Planning & Implementation, Knowledge/Expertise, Professional Approach to Work, Problem Solving, Team Approach to Staff Interactions, and Other Professional Interactions. This set is broader than the staff development goal discussed in this chapter.

As with any learner, practice dramatically affects the depth of acquisition and utility of application in new contexts. Each staff member is responsible for coordinating one or two of the thematic units for the year, so each individual has an opportunity to independently practice identifying the conceptual foundations and goals for a topic and to specify ways in which each of the six domains can be advanced by our program. During that process, I am available for consultation and can provide a level of guidance and instruction that is appropriate for each individual. The teachers get a similar opportunity to work independently or consult with me when they teach other teachers, either the student teachers that they supervise, colleagues at a professional conference, or teachers that attend the professional development sessions that the Children's School offers. For example, several teachers collaborated on a presentation about the ways that we integrate cooking activities into our thematic units and discussed the specific aspects of each developmental domain that can be intentionally fostered via cooking. Talking about the six domains with parents during conferences and with undergraduate interns provides additional opportunity for them to strengthen their own understanding.

My staff development examples thus far have focused on formal professional development that involved essentially the whole staff, with basic modifications or extra work with people who had weaker foundations. My informal, more individual, interactions with teachers typically focus on discussing why some part of the program did not work or how to help a particular child who is experiencing a developmental difficulty or delay in one or more areas. In such cases, like the example of fostering conflict resolution, I typically use the same cognitive principles to guide the discussion. Did we assume some prior knowledge, skill, or interest that the children did not have? Did we make the process, expectations, and so forth explicit enough for them to use as a guide? Did we intentionally connect with the children's existing knowledge or in other ways help them elaborate on the experience? Did we give them enough opportunities to learn and practice the desired skill to gain mastery? Did the program work better with some children than with others (older? more verbal? etc.)? In this way, I hope to reinforce the teachers' use of these metaprinciples so that they will eventually integrate them automatically into their instructional and assessment designs.

These examples demonstrate how I can strengthen the theory–practice link through both formal and informal coaching. Emphasizing the research link can enhance the whole system. My emphasis is heaviest on learning about research. We read and discuss research articles or reviews

that are relevant to issues that we are facing; staff members who attend conferences present abstracts of research sessions that they found helpful; and all of the researchers who conduct studies at the Children's School give brief presentations to our staff. In all of these contexts, I serve somewhat as a translator, or perhaps more of a "connector," trying to activate the prior knowledge that I know exists, to explicitly label and define concepts that may be presented in cryptic form, to elaborate points with examples from our shared experience, and to reiterate key concepts during a discussion. Although any one article or presentation is unlikely to dramatically affect our "system," it has been interesting to watch the depth of discussion develop over the course of repeated exposures to different studies within a research program or a particular subfield. For example, our staff discussions of the role of gesture in development and education have grown deeper with each presentation that one of our faculty gives (Alibali & Goldin-Meadow, 1993).

Involving the teachers more directly in research has benefits for them and the researchers. We have researchers talk with teachers prior to the beginning of a given study so that the teachers can offer suggestions about the design. Not surprisingly, they often comment about the interaction of a specific task with the children's prior knowledge (e.g., the potential impact of one year's "letter of the week" project on a study of children's ability to identify the initial letter of words presented orally, a study that was slated to happen just after "J" week). They suggest ways to make the child's task clear (both through explicit instructions and by using "games" that have a common script) and to make it interesting enough to get them through the often large number of trials necessary in experimental designs.

In my own lab, I choose to explore the aspects of development that most trouble, puzzle, or otherwise interest my teachers, and my research assistant involves the teachers in both the design of the task and of the report format, so that the teachers will be able to use the information gained to help them understand their children. The communication assessment in Appendix D is an example of this type of involvement with research. Because my lab is such an integral part of the school, the teachers both give and receive feedback in shorter cycles than is typical in research contexts. In this case, they suggested the topic, helped revise the assessment, and got data on almost all of their children within one semester. With the help of undergraduate students, we have developed similar assessments on a wide variety of topics, including comparison–contrast skills, leadership, decision making, cooperation, and so forth.

Overall, the benefit of this emphasis on the research links in the theory–research–practice triangle is that teachers' theoretical concepts deepen and become better integrated with their understanding of both research and practice. In addition, they have become more "experimental" in their classrooms, purposely trying different strategies with individual children or groups, in a more reflective, although not controlled, way than I had previously witnessed.

Parent Education

The case of parent education is both simpler and more difficult because of the limited interaction and responsibility that we have with parents. For most parents, with the notable exception of psychologists from the university and professional communities, prior knowledge about cognitive and social development is limited to practical experience with their own children and their children's friends, and access to theory or research is limited to what they hear in the popular media, which typically distracts them. We begin our parent education when prospective parents first visit our school by introducing them to the six domains of development in Table 12.1 and our rationale for the priority order. We discuss our educational program, and, in lay terms, the cognitive foundations for its design. We especially emphasize the goal-driven nature of our instruction and assessment approaches. Once parents have children attending our school, we begin more detailed descriptions of the ways that our program is designed to foster skills in particular domains, or the ways that certain activities, like cooking or dramatic play, can be used to foster development in all six domains. Appendix E includes sample parent newsletter articles, including one that focused explicitly on the metaprinciples underlying our use of thematic units, such as the "Ponds" study (Appendix B). Conference discussions with teachers provide yet another context for parents to develop an understanding of developmental theory in relation to their child.

We also begin our parent education about developmental research at the prospective parent stage. One requirement for entry into our program is that parents sign a blanket permission form for the child to participate in any research projects conducted at the Children's School. Helping them become comfortable with that requirement involves explicitly describing the low-risk types of research conducted and the high-quality procedures that we have developed to ensure that the children's experience meets all of the ethical standards and is consistent and well integrated with their

school experience. For some parents, it also involves countering misconceptions and fears about research that relate to their prior experience with medical research or highly publicized cases of ethical breeches. Once the family becomes part of our school, they can read abstracts of studies being conducted and summaries of completed studies in our monthly newsletter.

The most in-depth application of metaprinciples from cognition and instruction is with parents whose children are experiencing a developmental delay or difficulty. In these cases, the parents' models of development and of their child have a dramatic effect on their ability to understand the presenting problem, its underlying causes, and the steps that can be taken to improve the child's functioning, if not eliminate the causes altogether. One interesting example relates to the two children whose difficulties with conflict resolution were described earlier. Both children were in the same preschool class and their consistent and dramatic aggressive behavior was impacting the whole class negatively. Through careful observation of the contexts, triggers, patterns, and resolution strategies related to these aggressive episodes, as well as conversations with the parents about the nature of similar episodes at home, we diagnosed one child's difficulty as resulting from a lack of clear structure in the home and anger at the family situation. In contrast, we felt strongly that the other child's behavior was the result of physiological issues with proprioception and motor control. Our ability to work with the parents of both children was hampered considerably by the fact that neither set of parents shared our model of the child's behavior. The prior personal and cultural experience of the first family led them to describe their child as cute, funny, assertive, a negotiator, and rambunctious, so they were slow to respond to the needs the child was expressing through his aggression. The second family viewed their child as in control of his behavior and purposefully being oppositional, so they responded with increased strictness, punishment, and so forth. Our eventual success with both sets of parents, and ultimately with their children, depended heavily on our identification of the prior conceptions with which they entered the process, explicit discussion of alternate models and ways to distinguish between them, emphasis on connecting the scenarios experienced at home and at school with the models that best explain them, repeatedly over the period of an entire year, with sensitivity to the individual characteristics and needs of each parent.

It is clear that we integrate the cognitive metaprinciples into both our general parent communication and our work with parents whose children are struggling. Our goal for the general parent population is merely exposure, so we have no formal assessment of our success, although it would be an interesting study to conduct. For the parents whose children are struggling, we have a clearer goal for them to make good choices about diagnostics and interventions, as well as to have the relevant knowledge to advocate effectively for their children. As with assessment of the children themselves, assessment of our success with parents in these situations is essentially a longitudinal case study. Although the impact of cognition and instruction is evident in our approach as I have described it, it is insufficient for dealing with the socioemotional aspects of the situation, where counseling skills are essential.

Undergraduate Learning Experiences

Undergraduates are an interesting contrasting case to teachers and parents. They come to us with more current theoretical background—having taken child development recently, plus most courses here emphasize an information-processing approach and highlight research methods and findings. Also, they may have taken other research methods courses before taking the developmental course. On the other hand, most have limited practical experience with children, perhaps some babysitting or interactions with younger siblings.

For undergraduates, we have two learning options, one with goals for building practical skills for working with children and the other for building developmental research skills. Many of our students participate in both aspects of our program, but we have to design programs that can be taken in either order.

The practicum option involves a guided field experience designed to help students deepen their understanding of developmental psychology by assisting in a preschool or kindergarten classroom and discussing the ways that their experiences relate to the theories and research they have previously studied, as well as to new readings. The classroom observation, interaction with the children and teachers, and experimentation with strategies for promoting children's development yields the fodder for the course discussions. As the course instructor, I intentionally work with the students during our formal seminar time and our informal interactions at the school to explicitly label the episodes they describe with theoretical terms, to make connections between theories by comparing and contrasting their perspectives on interesting episodes, and to link episodes with the research presented in our course readings. By using these strategies each week with respect to a new reading topic, I offer the students opportunities to practice making the links and communicating explicitly about them. As the semester progresses, the students begin to identify the theoretical perspectives that are most useful for helping them understand their experiences in the classroom.

Individual students in the practice track also have the opportunity to work independently toward the goal of integrating theory, research, and practice by writing weekly entries in their course journal that explicitly discuss the connections and by developing a case study of one child. The case study is structured by the Children's School's six domains of development, and students gather information by naturalistic and structured observation, interviews with the teacher, and occasionally, interaction with the parents. Here again, the emphasis is on theoretical explanation for the child's development and prediction of what strategies might foster development, as well as links to research findings that support the student's claims. These two written projects, plus an oral presentation of the case study, serve as the assessment of each student's progress toward the goal of integrating their theory and research knowledge with educational practice.

The research option involves a research methods course with a laboratory component at the Children's School. The goal of the course is to help students acquire an understanding of the concepts and issues in developmental research and to provide hands-on experience in conducting developmental research. Because instructors other than myself actually teach the seminar portion of the course, my participation is limited to working with the students on the laboratory component. Nonetheless, the goal of integrating theoretical, research, and practical knowledge and the application of the cognitive metaprinciples are still a major part of the process. Because we are aware that the weakest aspect of the students' prior knowledge is typically the practical side of conducting research with young children, we have designed explicit procedures and support students' use of them by working closely with them during their initial lab setup and initial contact with the children. In our group introduction to the research procedures and in our involvement with each research group, we explicitly highlight the rationale behind our procedures (the theoretical principles, the research ethics, and the practical aspects of work with young children). As they progress from one lab to the next, we repeatedly emphasize the decision-making process underlying the design of the projects. Eventually, they develop a final project of their own design and then receive feedback from both me and their course instructor. During the inevitable revision process, we emphasize the design decision process explicitly and encourage links to research examples with which the students are already familiar. Although the course is only long enough to permit students to conduct one study of their own design, interested students have numerous opportunities to conduct research projects in the context of upper level courses, independent research with faculty members, and senior honors theses. Although I have no formal role in evaluating the students' progress in research, I continue to review their requests to use the Children's School laboratory and monitor the conduct of their research there. In that context, I have observed that the students make better research design decisions, understand my suggested revisions and the rationale for them more easily, and develop better interaction strategies in research contexts with young children as they gain more experience.

COGNITION AND INSTRUCTION IN THE LABORATORY SCHOOL AND BEYOND

Applying the cognitive technique of task analysis at an educationally practical level has significant benefits for designing effective instruction and assessments. We demonstrated this point most effectively with respect to the children in our laboratory school, but we are also witnessing the positive impact of the approach in our work with teachers, parents, and undergraduates. In a similar way, we have found the cognitive metaprinciples that I described to be broadly useful in focusing design discussions on effective strategies for both instruction and assessment. Constraints imposed by the enormous scope of applying both the task analysis and the metaprinciples across the curriculum for all learners require a streamlined approach for most aspects, with more detailed applications in only the most important or difficult cases. Nonetheless, we continue to improve our own applications and to spend a significant portion of our teacher training and consulting efforts encouraging others to use this G→P→A approach.

In fact, beginning in 1998, we founded an Early Childhood Professional Development Center[5] to develop ways of using our approach to help educators to improve their own programs. (See Appendix F for the center philosophy and a sample seminar schedule.) By familiarizing ourselves with trainees' programs in advance of training and by conducting

[5]Our Early Childhood Professional Development Center is supported by the Alcoa Foundation.

introductory activities at the seminars, we estimate the trainees' prior knowledge and existing practice. Our seminar activities and handouts explicitly detail our approach and provide visual examples. By encouraging sharing of ideas among trainers and trainees, we build links between seminar principles, existing practice, and future directions. Our 2 day and week-long seminars include opportunities for practicing the G→P→A alignment as it relates to diverse aspects of an early childhood program. We also explicitly emphasize our goal of teaching a design strategy that is individually applicable to diverse programs, rather than suggesting that participants mimic our specific program. Feedback during and immediately after each seminar reveals that trainees both understand the basic G→P→A Approach (Table 12.2) and anticipate being able to apply it to their program improvement efforts. More importantly, our subsequent interactions with both teachers and directors reveal that significant progress is occurring. Such reports indicate that the strategies of using task analysis and metaprinciples are applicable beyond the laboratory school and in diverse programs that are unlikely to have a cognitive psychologist on staff;[6] but, once again, formal study of the specific ways professional development impacts program improvement is needed.

In addition to the impact of dissemination efforts, such as those of our Professional Development Center, laboratory school practice such as ours can impact the field of cognition and instruction during the next 25 years in several ways. At some level, our efforts exemplify the ultimate goal of the field: to understand the processes of teaching and learning well enough to provide ideal learning environments for varied individuals at all levels of the system. As such, we serve as a cautionary reminder of the "big picture" and encourage others to broaden their research to include an integration of social, cognitive, and physical development in a realistic context.

Because that task may seem daunting, I suggest several more manageable, but highly valuable contributions that researchers could make toward the ultimate goal.

1. Develop practical techniques for streamlined task analysis.
2. Specify the set of metaprinciples that serves as the foundation for your instructional designs and write about them more fully than is typically allowed in our field's journals.

[6]In addition to our early childhood professional development work with educators in our community, I have applied the same G→P→A approach (Table 12.2) to the redesign of an elementary school curriculum, reviews of several college programs, and a training program for postcollege campus ministers. Theoretically, the approach can be applied to learners of any age and across many domains.

3. Experiment with assessments that are short and straightforward enough to be used for large numbers of children in school contexts.
4. Develop scoring systems and analysis techniques that can be used validly and reliably, even in nonstandardized contexts with a wide range of learners.

Then, take these new approaches and use them to set new goals for teacher training, to design effective instruction for teachers, and to assess their progress. For example, Minstrell cited the significant changes he has witnessed because of helping teachers learn to use research to address their own educational problems (chap. 4). This step is essential because there will never be enough well-trained researchers to fully apply even what we know now about cognition and instruction. Broad impact will be possible only when the skills are broadly distributed.

Finally, take collaboration to the next level, from the level of a whole course to a whole domain, to a full program, to an entire school. Psychologists in positions like mine do not have time to fully implement all of our ideas, let alone study the impact of the designs we develop, even for one set of learners in one domain. Enrich the field by collaborating with us during the next 25 years of Cognition and Instruction research.

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APPENDIX A

Samples From the Children's School Goal Specifications

3. COMMUNICATION—facilitating comprehension and expression skills beginning with oral and progressing to written language.

A. SPEAKING

Phonetics, Vocabulary, Grammar, Oral Expression

B. LITERATURE/READING

Story Listening

3→	4→	5→
enjoy books with pictures enjoy silly stories	listen attentively to story identify characters ask questions	predict next events
listen to story on tape		listen when peers read
recall main idea relate story to own exp.	recall plot in order (literal events) recall small details	listen for meaning and answer comprehension questions draw conclusions
fill in missing words identify missing object from set of four or class identify missing part of picture	fill in missing actions (not saying thanks)	use more abstraction in what's missing

Story Telling

3→	4→	5→
retell two or more facts from story read two times	retell story in own words identify beginning, middle, end	retells in order with details borrowed stories (new twist on an old favorite)
make up stories	use expressive language and sounds	tell original story use descriptive words illustrate/write own books
	simple story grammar (beginning, middle, end)	use standard story frame (once upon a time)

Story Analysis, Pretend Reading, Sounds & Symbols, Print Formats

C. WRITING

Letter Recognition/Formation, Writing Format, Writing to Communicate

4. DISCOVERY & EXPLORATION—fostering a positive attitude toward learning through questioning, observing, and experimenting with varied materials related to diverse themes.

A. APPROACH TO LEARNING

3→	4→	5→
positive attitude self-motivation / initiative accepting of mistakes as learning resourceful	complete task with persistence	plan for task (e.g., gather materials) seek more than one solution

B. COLLECTING AND OBSERVING

3→	4→	5→
aware of senses describe basic features	describe characteristics and behaviors of present and imagined objects	more complex description
collect and sort objects compare and contrast basic dimensions	classify and order added variation and # of dimensions	
count objects	estimate number measure with units create balance	use standard measure weigh objects
magnify objects associate objects (e.g., bird with nest)	record observations with drawing or photo	use standard symbols use graphs
recognize map	identify land and water relate personal experience to map	use simple map and globe

C. QUESTIONING & PREDICTING

D. EXPLAINING & REPORTING

E. NUMBER

Comparing, Sorting, Ordering, Number, Operations

F. SPACE (both two- and three-dimensional understanding)

Lines (components of shapes), Shapes, Position, Patterns

G. MEASUREMENT

Length, Weight & Volume, Temperature, Speed, Time, Money, Graphing

APPENDIX B

Outline and Excerpts From the Summer 1999 Pond Unit

Carnegie Mellon University Children's School
Ponds Unit
Summer 1999

Plan to Subdivide the Four Weeks of the Ponds Unit:

- Water (Week 1)
- Plants (Week 2)
- Animals
  - Fish, Frogs, and Turtles (Week 3)
  - Insects & Spiders (Week 4)

Likely existing concepts (depending on individual experience)

- Everything needs a place to live.
  - A pond is a small body of water.
  - Can describe water—typically wet, clear, cool, etc.
    - May know different forms of water.
    - Can describe ways people use water.
  - Can list and describe some plants and animals that live in or near ponds—typically ducks, frogs, turtles, fish, bugs.
- May identify basic parts of plants and what they need to live.
- May identify basic parts of animals and what they need to live.

What they're unlikely to understand is the concept of *habitat* and the *interdependence* of the living and nonliving things in a habitat. They're unlikely to link the features of plants and animals to the ways that they are *adaptations* to the particular habitat. These are the key points to emphasize in the unit. The concepts listed below expand on these basic points.

Concept of "A Pond as a Habitat"

- Habitat Basics
  - Living vs. nonliving things.
    - Living things need food, water, and air to stay alive.
    - Most living things grow and change.
  - Variety of living things (plants and animals).
  - Many different places to live.
    - Every living thing needs a place to live—a home.
    - Each living thing lives in a
      - HABITAT = A PLACE WHERE SOMETHING LIVES
    - Every habitat has living and nonliving parts.
    - A habitat provides food, water, air, temperature, safe spaces that a plant or animal needs.
    - Different habitats meet different needs.
    - A living thing also gives something back to a habitat.
      - Each living thing has a job to do.
  - In habitats, all the parts fit together.
  - Common needs, Diversity of approaches to meeting them in diverse habitats, interdependence
  - Importance of taking care of habitats

  - Water habitats
    - Earth has more water than land.
    - Two types of water habitats; freshwater and saltwater
  - Freshwater habitat (*ponds*, bogs, swamps, lakes, rivers)
    - Climate varies
      - Water can be cold or warm
      - Water can be still or flow fast
    - Plant & animal life depends on type of water
  - A *pond* is an enclosed body of fresh water that is smaller than a lake (i.e., still water but could be cold or warm)

Unit continues with concepts about each week of the unit

- Water (Week 1)
- Plants (Week 2)
- Animals—Fish, frogs and turtles (Week 3)
- Animals—Insects & spiders (Week 4)

Developmental Objectives for Focus in the Ponds Unit

Objectives for all six domains are listed in the unit. Key excerpts for two domains are included here.

3. Communication—facilitating comprehension and expression skills beginning with oral and progressing to written language.

Speaking

- Learn new vocabulary—habitats, pond, vapor, cattails, water lily, shelter, fins, gills, minnow, catfish, bass, amphibian, tadpole, reptile, antenna, metamorphosis ...
- Use body language, act out certain animals/pond life, role play
- Identify and name pond/pond life objects
- Convey ideas regarding pond, discuss cycles and activities that go on at a pond

Literature/Reading

- Read books about the pond and pond life
- Predict what happens next in stories and/or life cycles of pond life
- Retell stories and/or life cycles in correct order
- Tell original stories involving pond habitat or pond life
- Recognize words related to pond and identify the word when it is next to a picture

Writing

- Dictate pond stories and write some words from story
- Make books, sign, pictures related to pond
- Label categories for sorting pond items

4. Discovery & Exploration—fostering a positive attitude toward learning through questioning, observing, and experimenting with varied materials related to diverse themes.

- Collect and sort items from pond according to various categories such as plant vs. animal, living vs. nonliving, land vs. water, insect vs. reptile, fish vs. mammal
- Ask questions about pond/pond life
- Observe the various types of pond life at the pond
- Describe characteristics and attributes of pond items collected
- Count items relating to pond
- Identify the different parts of an insect or plant
- Magnify, measure, and weigh pond items
- Compare and contrast the length and weight of items
- Record observations of pond/ pond life with drawings & charts

- Make a simple map of the pond
- Understand and follow sequences in relation to pond life cycles and water cycle
- Add and subtract using pond related objects
- Match pictures with pond objects collected

Pond Resources found at the Children's School:

Puzzles / Games:
- Pond Life
- Duck Pond
- Fishing Game
- and so on

Manipulatives:
- Insect Collection
- See and Do Nature Series
- and so on

Computer CDs:
- Sammy's Science House—Seasons at the Pond
- Amphibians and Reptiles
- and so on

Pond Books found in the Children's School Library

Habitats / Pond:
- *Birds and Their Environment*, Frances Todd Stewart
- *All About Water*, Melvin Berger
- and so on

Plants:
- *The Story of the Root-Children*, Sibylle von Olfers
- *The Giving Tree*, Shel Silverstein
- and so on

Frogs, Fish, and Turtles:
- *The Magic Fish*, Freya Littledale
- *The Tortoise and the Hare*, Aesop Fable
- and so on

Insects and Spiders:
- *Feely Bugs*, David Carter
- *The Very Busy Spider*, Eric Carle
- and so on

Activities Bibliography

Exploring Water and The Ocean, Gayle Bittinger (Green)
The Kids' Nature Book, Susan Milord (Salmon)
and so on

APPENDIX C

Samples From the Children's School's Kindergarten Conference Form

Communication

Speaking:
- ✓ uses 100% intelligible speech
- ✓ has age-appropriate vocabulary
- ✓ speaks in complete sentences
- ✓ participates in conversation
- ✓ participates in group discussion
- ✓ presents information to the group

Beginning Reading:
- ✓ listens attentively for meaning
- ✓ answers comprehension questions
- ✓ follows left to right progression
- ✓ follows top to bottom progression
- ✓ identifies rhyming words
- ✓ recognizes upper case letters A through Z
- ✓ has been exposed to lower case letters a through z
- ✓ finds name on list and writes a check mark

Beginning Writing:
- ✓ forms upper case letters A through Z
- ✓ prints full name
- ✓ asks for spellings of words

Name ... (teacher writes a paragraph of evidence, explanation, and suggestions)

Discovery & Exploration

- ✓ exhibits a positive approach to learning
- ✓ completes an age-appropriate task with persistence
- ✓ asks Who? What? Why? Where? When? How? questions
- ✓ seeks answers through exploration

Beginning Math:
- ✓ can count from 1–30 by rote
- ✓ counts to 20 with 1 to 1 correspondence
- ✓ forms numerals from 1–20
- ✓ recognizes numerals 1–20
- ✓ recognizes and names complex shapes
- ✓ recognizes and forms simple patterns
- ✓ classifies and orders objects independently
- ✓ compares and contrasts length, weight, volume
- ✓ recognizes time cycles
- ✓ tells time by hours
- ✓ understands use of money for buying
- ✓ reads and forms bar graphs

Name ... (teacher writes a paragraph of evidence, explanation, and suggestions)

APPENDIX D

Sample Report From a Structured Assessment of Communication

Child's Name *NB* Date Observed *4/29/99*
Observer's Name *Jolene*

The ABC Game—A Communication Task

NB was asked to *find her name* on a list of all 23 kindergartners. She was able to do this right away. She was also able to make an X by her name.

Next, she was asked to *name rubber letters* of the alphabet and correctly named all 26 upper and 25 lower case letters (she didn't know the q, but it's an odd q, with a short straight tail).

When *listening* to a brief (approx. 6 minute) story tape, NB was 100% engaged with the book, and 100% engaged with the tape, during the first 4 minutes. She seemed to enjoy the story, but was somewhat distracted by the tapeplayer. Her answers to several *comprehension* questions indicated that she paid attention and understood the story. NB showed a strong *interest in words*. Answering one question, she said the giant was big, hairy, scary, mary, gary. Also, she was very interested in oversized words in the text.

When asked to *follow on a page* read aloud with her finger, NB was able to follow from top to bottom and from left to right.

NB appropriately *named the story* "The Giant." She knew how to spell THE, and carefully *sounded out* GYNT. NB was able to *write* her first and last name.

APPENDIX E

Sample Parent Education Articles From the Children's School Monthly Newsletter

Director's Corner (for November '98 Newsletter)

The development of *Communication Skills* is an important aspect of the preschool years because these skills enable increasingly effective social interaction and increasingly complex learning. Young children's listening, speaking, reading readiness, and writing readiness skills contribute to their foundation for success in elementary school.

Communication is a part of the Children's School day from the moment the teacher and child greet each other at the car through dismissal. By repeating standard phrases, songs, and fingerplays, together with relevant visual cues, we encourage children's listening comprehension and fluent speech. As the teachers introduce and reinforce concepts related to our themes, the children learn and begin to use new vocabulary. While exploring these topics, we encourage children to ask questions, describe their observations and experiences, and formulate explanations for events. Frequent story reading and re-reading helps children practice their comprehension skills, as well as promoting interest in books. Teachers also provide a wide variety of opportunities for sharing personal stories and knowledge informally. We encourage formal sharing via "Sharing Days" in the preschool and "Discovery Table" presentations in the kindergarten.

In addition to promoting oral communication, we encourage children's interest in written communication by providing frequent exposure to reading and writing in inviting contexts. Children have many opportunities for quiet "reading" times to explore books individually. We talk about letters, the way they look, the way they sound, and the places we see them in our environment. In the preschool, names have special significance, as do

words like "open" and "closed." Similarly, our writing centers are places for children to experiment with drawing and writing. Teachers follow the children's interest with help in letter formation and spelling. Children in the preschool are also invited to dictate stories that can then be reread in the classroom and at home. In the kindergarten, the opportunities for exploring reading and writing are expanded to include the "Morning News," the "Wall of Words," journal writing, group stories, and many other activities. In all cases, the teachers tailor the program to the needs of each year's class and modify activities to challenge individual children ranging from prereaders to fluent readers.

A short walk through the school while the program is in session will provide a vibrant demonstration of the many ways our teachers work to promote strong comprehension and expression so that our children become effective communicators. Feel free to join us one day soon!

Director's Corner (for March '00 Newsletter)

Thanks, again, to the many parents who helped make our Heritage Celebration a wonderful event! I enjoyed interacting with all of the families and hearing about how much the children have learned from the China and Canada units. As you probably know, such in-depth units are rarely attempted in other early childhood programs and some educators claim that it is impossible for young children to learn about topics beyond their immediate environments (e.g., China, dinosaurs, and outer space) in developmentally appropriate ways. At the Children's School, we utilize key principles from cognitive psychology to help us create ways for our students to experience concepts directly and to build a strong knowledge base about a variety of topics that interest them.

Build on Prior Knowledge
Before each unit begins, the teacher who has volunteered to be the Theme Leader collects factual information about the topic and identifies concepts that the children are likely to know already as well as those that are within their reach. They prepare a booklet for the whole staff that includes these concepts, as well as more in-depth background information that we might need for answering children's questions as they arise. Each unit begins with circle time discussion of what the children already know about a topic. The 4's and kindergarten teachers often record this information on chart paper as a list or web that can be consulted and expanded throughout the unit.

Make Thinking Explicit
The Theme Leader also collects a wide variety of materials from the Children's School shelves and local libraries that will help the teachers and children use their senses to observe important properties related to the topic. We utilize a wide range of fiction and nonfiction books, particularly ones with clear photographs and we attempt to have authentic artifacts for the children to handle. For example, you might have visited the Beaver Museum in Canada during the Heritage Festival to see the beaver artifacts that we borrowed from the Carnegie Museum and the beaver dam that the kindergartners designed.

Emphasize Links
Studying one topic for an extended period of time allows the children to explore multiple aspects of a concept. For example, the Forest unit involved a comparative study of the plants and animals in Deciduous and Coniferous Forests. Throughout the unit, teachers routinely combine verbal and visual representations, provide a variety of exploration activities related to the topic, and intentionally ask children to recall aspects of prior related lessons. We also sequence our units to maximize the useful connections between them. In the preschool, our China unit was purposely designed to link with our Where We Live, What We Wear, and What We Eat units in the fall.

Provide Practice Opportunities
Both proficiency and efficiency of knowledge application are dependent on repeated practice in a variety of contexts. Within a thematic unit, children have varied opportunities to acquire, strengthen, and refine their concepts via experimentation, stories, dramatic play, art, games, computer activities, etc.

Expect Individual Variability
The diverse opportunities that children have for exploring a theme throughout our daily schedule allow for individual choice related to the special interests and talents of each child. At the same time, the availability of activities that are not related to the theme allows children to explore other interests and the teachers to work on skill development in all areas, regardless of particular thematic relation. The broad range of themes that we study in a given year are purposely designed so that there will be a few that spark particular excitement from each child.

Feel free to visit the school to see the key principles in action. Reading books and talking with your child about our unit topics will give you a chance to observe his or her developing concepts. For topics of special interest to you, consider talking to your child's teacher about how you can help extend the theme at school or at home.

APPENDIX F

Professional Development Center Philosophy and Sample Seminar Schedule

Early Childhood Professional Development Center
Sponsored by the Children's School
at Carnegie Mellon University
Supported by the Alcoa Foundation

- The purpose of the Professional Development Center is to improve the reflective practice of early childhood educators by
  1) training educators to use clear objectives for children's development as the basis for developmentally appropriate program and assessment, and
  2) consulting with administrators and their staff members during the process of implementing new approaches.

- Our Professional Development Center programs are based on the philosophy that trainers are most effective when they are master teachers themselves, have advance knowledge of the contexts in which trainees work, and can have long-term contact with trainees for both initial training and follow-up consulting. Similarly, trainees learn best in small groups that are conducive to discussion, when they have detailed documentation of seminar principles and clear practical examples to follow, and with strong support from their administrators and active consulting on implementation after the initial training.

- We design unique programs that equip individual educators or staffs to apply the seminar principles to their centers based on their students, staff, clients, and facilities.

Developmentally Appropriate
Goals, Program, & Assessment
The Children's School, Carnegie Mellon University

Goals for Day 1

- Using developmentally appropriate goals to structure program and assessment design
- Developing practical classroom strategies for fostering the development of preschool and kindergarten children
- Using thematic units that meet your program's specific goals

9:00am	Introductions / Overview
9:30am	The Goals → Program → Assessment Approach
10:00am	Identifying Goals for a Child's Development
10:30am	BREAK
10:45am	Designing the Program to Meet Goals
12:00pm	LUNCH
12:30pm	Studying Themes to Meet Goals
1:00pm	Exploring Unit Samples
2:30pm	BREAK
2:45pm	Assessing Progress → Goals
3:45pm	Closure / Q & A / Evaluation

Goals for Day 2

- Exploring ways to use Phys Ed, Computers, Science, and Visual Arts to provide a variety of unique learning experiences that meet your goals and provide evidence of children's growth

9:00am	Introductions Review of the Goals → Program → Assessment Approach (GPA)
9:30am	Visual Arts Exploration (Red Room)
10:45am	Computer (Kindergarten)
12:15pm	LUNCH
12:45pm	Science (Green Room)
2:00pm	Physical Education (Outside, we hope!)
3:30pm	Closure / Q & A / Evaluation

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Themes in Cognitive Science and Education

Earl Hunt
University of Washington

The chapters in this part of the volume range over a wide variety of processes and topics. Processes range from Carver's focus on the interaction between social, cognitive, and motor maturation in young children (chap. 12) to Anderson and Gluck's analysis of young adult problem-solving skills based on traces of their eye fixations as they scan the displays from an intelligent tutor (chap. 8). Topics range from Lovett's discussion of university-level statistics (chap. 11) to Reiser, Tabak, Sandoval, Smith, Steinmuller, and Leone's instruction in high school biology (chap. 9). In spite of this variety, and probably because the symposium was limited to less than 3 years duration, no attempt was made to include chapters that cover the full curriculum at all grades and for all topics.

For all of this diversity, I believe that there are some common ideas in this set of chapters. I am not sure whether they should be called themes within the chapters or dimensions along which the chapters can be compared. The first theme (or dimension) deals with the balance between engineering and science in instructional applications of cognitive science, and the second deals with the role of the teacher in such applications. I also comment on the issue of classroom culture and group work. This topic—too often ignored in the application of cognitive science to education—was introduced at the symposium by Ellis and Gregoire but, unfortunately, it could not be included in this book.