Transforming Schools Into Communities of Thinking and Learning About Serious Matters

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In this article, a program of research known as Fostering Communities of Learners is described. This program is in place in several schools and classrooms serving inner-city students from 6 to 12 years of age. Based on theoretical advances in cognitive and developmental psychology, the program is successful at improving both literacy skills and domain-area subject matter knowledge (e.g., environmental science and biology). Building on young children's emergent strategic and metacognitive knowledge, together with their skeletal biological theories, the program leads children to discover the deep principles of the domain and to develop flexible learning and inquiry strategies of wide applicability.

In this article, I describe a program of research referred to as Fostering Communities of Learners (FCL) and how I came to develop the program. The aim of the program is to design an environment in urban classrooms where grade school children learn to think deeply about serious matters.

Jerry Bruner (1996), who visited these classrooms, singled out four crucial ideas underlying FCL: (a) agency, (b) reflection, (c) collaboration, and (d) culture:

> The first of these is the idea of *agency:* taking more control of your own mental activity. The second is *reflection:* not simply ''learning in the raw'' but making what you learn make sense, understanding it. The third is *collaboration:* sharing the resources of the mix of human beings involved in teaching and learning. Mind is inside the head, but it is also with others. And the fourth is *culture,* the way of life and thought that we construct, negotiate, institutionalize, and finally (after it's all settled) end up by calling ''reality'' to comfort ourselves. (p. 87)

Unfortunately, I could not have said it better myself.

There are three main themes running through this article. First is the theoretical question of learning to learn, or deuterolearning, a topic with an honorable history in psychology and education. Psychologists have been interested in this form of agency because of well-recognized stumbling blocks to lasting learning: inert knowledge and passive learning. Students acquire facts that they cannot access and use appropriately; their knowledge is said to be inert (Whitehead, 1916) or welded (Brown, 1974) to its original occasion of use. Furthermore, students experiencing learned helplessness (Dweck, 1975) do not readily engage in intentional, self-directed action.

During my career, I have been concerned with methods for helping passive learners achieve agency and reflection by introducing them to learning strategies that lead to transfer, or the flexible, appropriate, and even creative use of knowledge. Ideally, understanding leads to generative, inventive, and experimental use of knowledge as well as the ability to reflect on one's own activity. This area of research is known as metacognition (Brown, 1975). Historically, there has been a tendency to think of such processes as domain-independent. But one cannot learn in a vacuum—being an expert novice (Brown, Bransford, Ferrara, & Campione, 1983) can take one only so far. In more recent years, I have become increasingly interested in what it is that children are required to learn and where and how they are required to learn it. The *what* of learning is the content, the curriculum or the domain, if you will. The *where* and the *how* of learning are the situation, or, in the case of FCL, the collaborative culture.

A second leitmotiv of this article is the contribution of basic and applied research. The reason I wrote the article is because I received an award for the application of psychology, primarily for my work in classroom settings. This is interesting because for most of my career, I studied children's learning in laboratory settings. My change in focus was gradual. Even though the research

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setting, laboratory versus classroom, changed dramatically, my goals remained the same: to work toward a theoretical model of learning and instruction rooted in a firm empirical base. I regard the classroom work as just as basic as my laboratory endeavors, even though the situated nature of the classroom research lends itself more readily to practical application. In the classroom, just as in the laboratory, I am in the business of devising design experiments (Brown, 1992; Collins, 1992) based on theoretical concepts that delineate why they work and thus render them reliable and repeatable.

There is no doubt that the choice of classroom or laboratory studies involves a trade-off between experimental control and richness and reality. The classroom is not the natural habitat of many experimental psychologists, and their methods have not evolved to capture learning in situ. Indeed, in the one grant proposal I had totally rejected, reviewers accused me of abandoning my experimental training and conducting "quasi-experimental research in pseudonaturalistic settings!" This was not intended to be a flattering description of what I took to be microgenetic studies of learning in classrooms. Nonetheless, as a personal research strategy, I find that switching back and forth from both types of settings enriches my understanding of a particular phenomenon.

The third thesis of this article is that a knowledge of developmental psychology is not just nice but necessary if one wants to study learning in children, in whatever setting one chooses. Even though the major overarching psychological learning theories had their impact on educational practice, for better or for worse, developmental theories rarely did. The one exception is Piagetian theory, which often has been used to emphasize what children cannot do rather than what they can achieve (Brown, Campione, Metz, & Ash, in press).

Ideally, as a designer of learning environments I should be a primary consumer of information from developmental psychology, to use a biological metaphor. Many of the most talented developmental psychologists spend a great deal of time arguing about what's biological about young children's thought. I need that information to design environments that encourage the growth of biological knowledge. But, by the same token, developmental psychologists should be primary consumers of design experiments that show what it is that children are ready to learn easily and what is resistant to exquisitely designed instruction.

Received Wisdom About Child as Learner

My own early research efforts were aimed at mapping *bandwidths of competence* (Brown & Reeve, 1987), or, if you will, zones of proximal development, through which children can navigate at various times and various speeds (Vygotsky, 1978). While not ignoring the fact that young children are often less adept learners than are older children, I took part in the movement to show earlier competence than was supposed, to offset the relatively pessimistic view of child as learner that existed when I began. At the very least, the glass half-full is a more positive metaphor through which to view children's learning than is the glass half-empty. But when I began to study the child as learner, there were four major perceived impediments to children's learning.

Learning Capacity

There was a widespread belief that children are fragile learners because they lack mental capacity per se. This theory dates back to the turn of the century and is still alive today. And when background knowledge is controlled, as when no one "has" it, undoubtedly older students outperform younger learners. This is true in a wide variety of situations that require effortful learning.

Strategic Intervention

A great deal of work in the 1970s, including my own (Brown, 1978), provided evidence that children's problems in learning were not simply a matter of mental capacity; the main culprit was children's inability to make use of what capacity they had. Passive in the face of instructions to learn, children were not known to recruit classical strategies to help them. Trained to use a variety of strategies, such as classifying, organizing, summarizing, and so forth, children dramatically improved their learning performance. But there was a catch: When left to their own devices, there was little evidence of continued use (maintenance) or flexible deployment (transfer) of these strategies.

Metacognition

Gradually, it became apparent that children's failure to make use of their strategic repertoire was a problem of understanding; they had little insight into their own ability to learn intentionally; they lacked reflection. Children do not use a whole variety of learning strategies because they do not know much about the art of learning; they fail to appreciate the constraints of limited human memory capacity. Nor do children know how to alleviate the problem by using clever tactics. Furthermore, they know little about monitoring their own activities; that is, they do not think to plan, orchestrate, oversee, or revise their own learning efforts. These are complex problems of metacognition.

Yet, even in problematic domains that demand effort and ingenuity, young children's strategic and metacognitive limitations are overstated. When very young children are asked to perform meaningful activities in hospitable environments (remembering the location of a desired object, etc.), they are strategic and monitor their performance quite successfully. One of my favorite examples of young ingenuity is that of three-year-olds who were asked to remember under which of three cups a toy dog had been hidden. One child looked at the target cup and nodded yes and then looked at the nontarget cups and nodded no. Another three-year-old sneakily marked the correct cup by resting his hand on it; another moved the correct cup to a salient position—yes, cheating. They didn't know the rules of the game, but they knew about remembering. They were anything but passive and nonstrategic (Wellman, Ritter, & Flavell, 1975). This example involves strategies and the dawning of metacognition, a combination apparent in children as young as 18 months under the right conditions (Brown & DeLoache, 1978).

Universal Novices

Historically, however, it was assumed that young children are less effective learners than their older counterparts. The fact that the first five years of life represent an enormous growth in linguistic and conceptual competence did not allay that opinion. It is true that, because of their general lack of knowledge and expertise, children have been referred to as "universal novices" (Brown & DeLoache, 1978). But it is important to make the distinction between *ignorance* (i.e., lack of knowledge within which to reason) and *stupidity* (i.e., the inability to reason within knowledge fields one does understand). Children are ignorant in many ways but certainly not stupid.

For example, consider the classical analogy task, *A:B::C:D*. Piaget, Montanegero, and Billeter (1977) believed that the ability to solve problems of this type was part of formal operational thought, and this task is still used to select graduate students (Miller Analogies Test); however, estimates of this ability typically confound knowledge and reasoning. When children fully understand the basis of analogy (e.g., simple causality, such as cutting, breaking, or wetting) or the relation involved is a thematic one (*bird:nest::dog:doghouse*), even preschool children can achieve success. Take, for example, a four-year-old child who just correctly solved a series of thematic analogies. The child looked at the *A:B::C:?* problem, *bird:bird nest::dog:?* Without even considering the choices, the child answered incorrectly, "puppy."

Child: "Bird lays eggs in her nest. Dog . . . dogs lay babies—um—and the name of the baby is puppy."
Experimenter: "Let's look at our pictures [choices]."
Child: "I don't have to look. The name of the baby is puppies."
Experimenter: "Just one look."
Child: The child looks and selects the correct picture, a doghouse (even though a picture of a puppy is present as a choice), but refuses to justify the correct solution, which is *lives in*.

As the experimenter prepared the next problem, the child was heard muttering in the background, "And the name of the baby *is* puppy" (Goswami & Brown, 1990).

Predisposition to Learn in Privileged Domains

Until now, I have concentrated on constraints on children's learning interpreted in a negative sense. Another branch of developmental psychology turned in the other direction, looking at young children's positive biases to learn certain privileged classes of information readily and early in life. We now know that young children attend selectively to certain sources of information rather than others. To give just one example, infants learn rapidly about what makes objects and people move. Young children show an early understanding that animate objects have the potential to move themselves because they are "biological stuff"—they obey what Gelman (1990) called the "innards principle of mechanism." Inanimate objects, in contrast, obey the external–agent principle; they cannot move themselves but must be propelled into action by an external force. And that force must be adequate for the job, as even 18-month-olds know when playing with sticks and strings as means for pulling and pushing (Brown, 1990).

Fundamental to learning, from this position, is a search for cause, for determinism and mechanism. Children implicitly assume that events are caused, and it is their job to uncover potential mechanisms. Indeed, they overdetermine cause, sometimes blinding themselves to essential notions of randomness and chance—a big problem in learning biology. These initial biases constrain what is selected from the range of available perceptual inputs to form the basis of emergent categories. The early differentiation between the properties of natural and artificial kind provides the impetus for growing knowledge about biological and physical causality. I discuss the advantage of capitalizing on the importance of understanding children's natural precocity to learn about biological mechanisms when designing environments in which they must learn about biological phenomena.

The Contents and Culture of Learning

I turn now to what children are required to learn and when they are required to learn it. During the 1970s, psychologists interested in learning gradually shifted from the study of how learners remember lists of words, pictures, and paired associates to a concentration on how learners understand coherent content. They began to look at the acquisition of expertise within a domain—gained over long periods of time through concentrated and self-motivated learning (e.g., chess, cooking). Contemporary learning theorists concentrate on how learners come to understand disciplined bodies of knowledge characteristic of academic subject areas (mathematics, physics, history, biology, etc.). My own research also reflected a shift to the study of learning, remembering, and understanding complex texts, which in turn led to studies of reading comprehension and comprehension monitoring in specific content areas, notably environmental science.

Reading Comprehension

Texts are understood and re-created in the telling. Understanding texts requires strategies and self-monitoring of a qualitatively different kind than does rote learning. The subjective judgment required to monitor whether one has understood texts presents the developmentally young with difficulty, which is not surprising given the problems college students have with the illusion of comprehension. So, my colleagues and I began a series of studies to help children learn from texts, "training" individual strategies such as questioning, clarifying, and summarizing to help them monitor their progress. This step was the precursor to a major change. Together with Annemarie Palincsar, I became involved in the design of a reading-comprehension program, reciprocal teaching (RT), that involved both the content and the culture of learning (Palincsar & Brown, 1984).

The Culture of Learning

RT is a way of conducting reading groups. Six or so participants form a group, with each member taking a turn leading a discussion about an article, a video, or other materials they need to understand. Initially, an adult teacher or an older student takes a turn as leader with the younger group members following suit, but gradually the group becomes capable of conducting its own reading activities in the absence of an adult. The leader begins the discussion by asking a question and ends by summarizing the gist of the argument to date. Attempts to clarify any problems of understanding take place when needed, and a leader can ask for predictions about future content if it seems appropriate. Questioning, clarifying, summarizing, and predicting are excellent comprehension-monitoring devices. Quite simply, if one cannot ask a question or summarize a main point, one does not understand, and one had better do something about it. Because thinking is externalized in the form of discussion, beginners can learn from the contributions of those more expert than they, and teachers or tutors can diagnose a reader's competence. As an intervention, RT was a success. I cannot begin to give details of the actual procedure and data from a 10-year series of studies, but I give a few examples.

The program has been used primarily with at-risk readers (from first to eighth grade). My initial examples are taken from 9–10-year-olds who spent 20 days reading simple texts centered on a coherent body of knowledge about the lifestyles of animals (camouflage and mimicry, protection from the elements, extinction, parasites, natural pest control, etc.; Brown, Campione, Reeve, Ferrara, & Palincsar, 1991). These themes repeated across texts, were taken up in discussions, and also were featured in daily independent tests of comprehension. Note that all of the measures involved independent learning and transfer in addition to group understanding. Students were asked questions of various types, but, most important, on each text they had to solve a problem by using analogy to past examples. In a very real sense, the students were required to learn cumulatively by example as well as to read intelligently.

The daily independent test results are shown in Figure 1. There were two RT groups: explicit, where the analogous materials across passages were stressed by the teacher, and implicit, where the analogies were left implicit for the children to pick up. Because they did this spontaneously, the implicit–explicit variable produced little effect. As can be seen in Figure 1, the RT groups outperformed a pair of matched control groups: a practice group that read all the passages and took all the tests but did not participate in RT sessions and an untreated control group that took only the pretest and the posttest. Note that even one year after the study, the RT groups maintained their high level of performance.

In Figure 2, one can see that on novel test passages that probed independent transfer, the RT students began performing well on basic fact retention (by design). However, the ability to make inferential assumptions, summarize the gist, and solve problems by analogy to previous passages improved greatly. In Figure 3, one can see the improvement over time in the ability to solve problems by analogy. Here the effect of explicitly stressing the analogy did have an effect, albeit one that dissipated by the end of the study. Note the long-term maintenance one year after the study terminated.

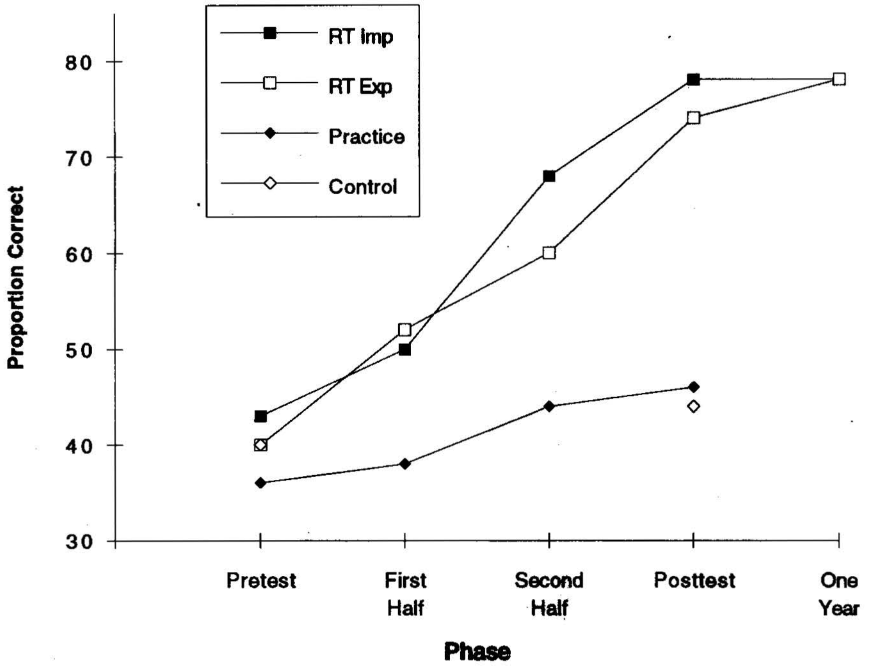
A minilearning community developed during RT, one intent not only on understanding and interpreting texts as given but also on establishing an interpretive community (Fish, 1980) whose interaction with texts was as much a matter of community understanding and shared experience as it was strictly textual interpretation. It was to capture this influence of common knowledge, beliefs, and expectations that the notion of a community of learners was developed. For the past 10 years or so, my colleagues and I have been gradually evolving learning environments that deliberately foster interpretive communities of grade school learners (Brown, 1995) in which RT remains the reading component. I continue to track the recognition and the use of analogy as part of the community discussions and give a flavor of those data here. In these extended discussions, I scored explanations and argument structures both within the community of learners and in laboratory settings.

I start first with analogies to continue the theme. In Figure 4, I show the spontaneous production of analogies in the discourse of 10-year-olds over three units of study, which took place over a school year. Considering analogies that occurred spontaneously as explanatory strategies, the proportion of surface analogies decreased, and the proportion of deep analogies increased (Brown, 1992). Take an analogy between a car and a human body; a surface analogy would involve the headlights and the eyes, whereas a deep analogy would compare the engine and the heart. With increasing knowledge, children progress from superficial analogy to deep analogy to explain mechanisms (e.g., from ''plant stems are like straws'' to analogies based on a deeper understanding of underlying biological mechanisms, such as ''plants are food factories''). I believe that this progression reflects the increasingly coherent and mechanistic nature of children's biological theories rather than age per se. But the point is contentious (Gentner, 1989).

Given such data, I typically turn to my laboratory to see what happens under more controlled conditions. For example, I (Brown, 1992) took a separate sample of 10-year-olds and gave them six days of story comprehension tasks, with 4 minipassages per day (24 in all). Each passage contained an analogy to be solved in reference to previous passages. This microgenetic study confirmed the increase in problem solution, particularly in the solution of deep analogy, as shown in Figure 5. As a further check, I gave another sample of children from 8 to 12 years of age the analogies that were actually produced by

Figure 1

Independent Comprehension Scores of High-Risk Third Graders in Four Groups: Reciprocal Teaching Implicit (RT Imp), Reciprocal Teaching Explicit (RT Exp), Practice, and Untreated Control



Note. From "Interactive Learning and Individual Understanding: The Case of Reading and Mathematics" (p. 148), by A. L. Brown, J. C. Campione, R. A. Reeve, R. A. Ferrara, and A. S. Palincsar, 1991, in L. T. Landsmann, *Culture, Schooling, and Psychological Development,* Norwood, NJ: Ablex. Copyright 1991 by Ablex. Adapted with permission.

children in the classrooms. These novice control students were given the same problems and asked to choose the best solution. Their choice was between a deep and a surface analogy, or a nonanalogy. As can be seen in Figure 6, preference for analogy increased with age, and this effect was carried by the increasing preference for deep analogies. Although this shift in preference, from surface to deep analogies, could be age-dependent, the classroom work suggests that the shift is knowledge-based, occurring microgenetically within a year as readily as cross-sectionally across several years.

Trends discovered in spontaneous classroom discussions can be tested in the laboratory, and vice versa. For example, analysis of classroom discussions suggests that the conditions of spontaneous use of explanation may be developmentally sensitive. First, impasse-driven explanation occurs in the face of breakdowns in comprehension, which is followed by the use of explanation to help resolve annoying inconsistencies. Then, spontaneous explanation is used in the absence of comprehension failure or obvious inconsistencies as learners continually revise and deepen their understanding of complex causal mechanisms. This microgenetic progression is shown in Figure 7.

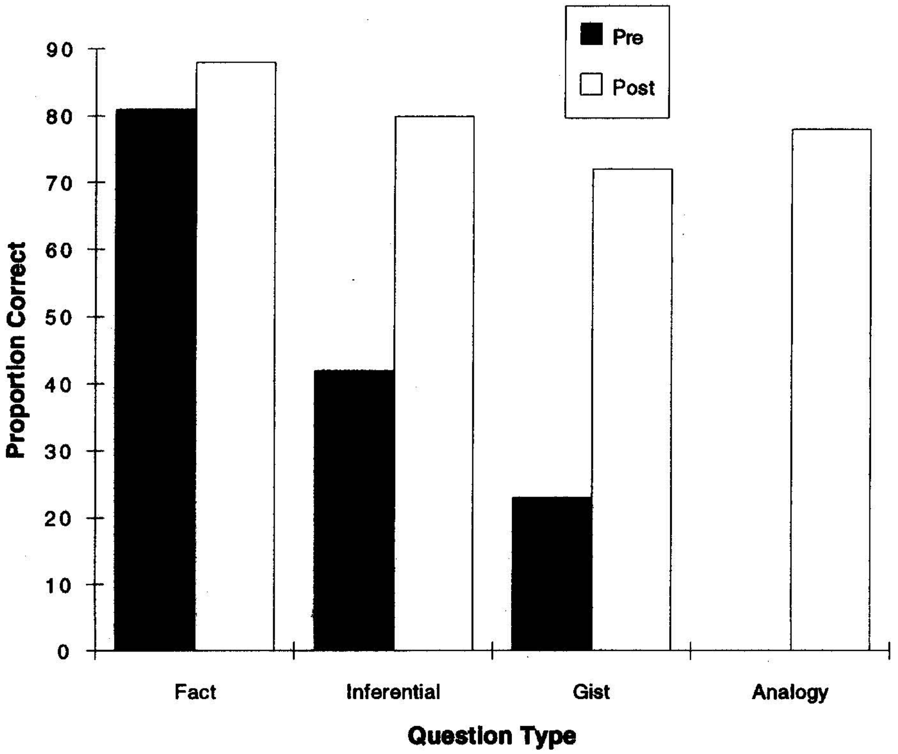
Faced with this apparent trend in classroom discussions, my routine procedure is to set up controlled laboratory studies to evaluate whether the developmental trend can be reproduced under experimental control. Similarly, when faced with a developmental effect in the laboratory, I am primed to watch for its occurrence in the morass of classroom discourse. This cross-fertilization between settings enriches my understanding of the developmental phenomenon in question. I nevertheless regard neither aspect of the work as basic or applied. To me, this is theoretically driven research of practical value and practically driven research of theoretical value. Theoretical advances can emerge from both the laboratory and the classroom setting. They are just that, different cultures whose features must be included in the description of the data they produce, the essence of design experiments.

Fostering a Community of Learners

In this section, I describe my attempts to turn urban grade school classes into science learning communities. The FCL project involves corridors of classrooms, sometimes whole schools, including primarily 6–12-year-old minority students. Obviously, I cannot describe the program in detail. Here, I concentrate on the main philosophy and the science "curriculum" that is practiced.

The means by which a metacognitive culture of learning is set up is summarized in Figure 8. At its simplest level, there are three key parts. Students engage in

Figure 2
Independent Comprehension Measures of the Reciprocal-Teaching Groups as a Function of Question Type



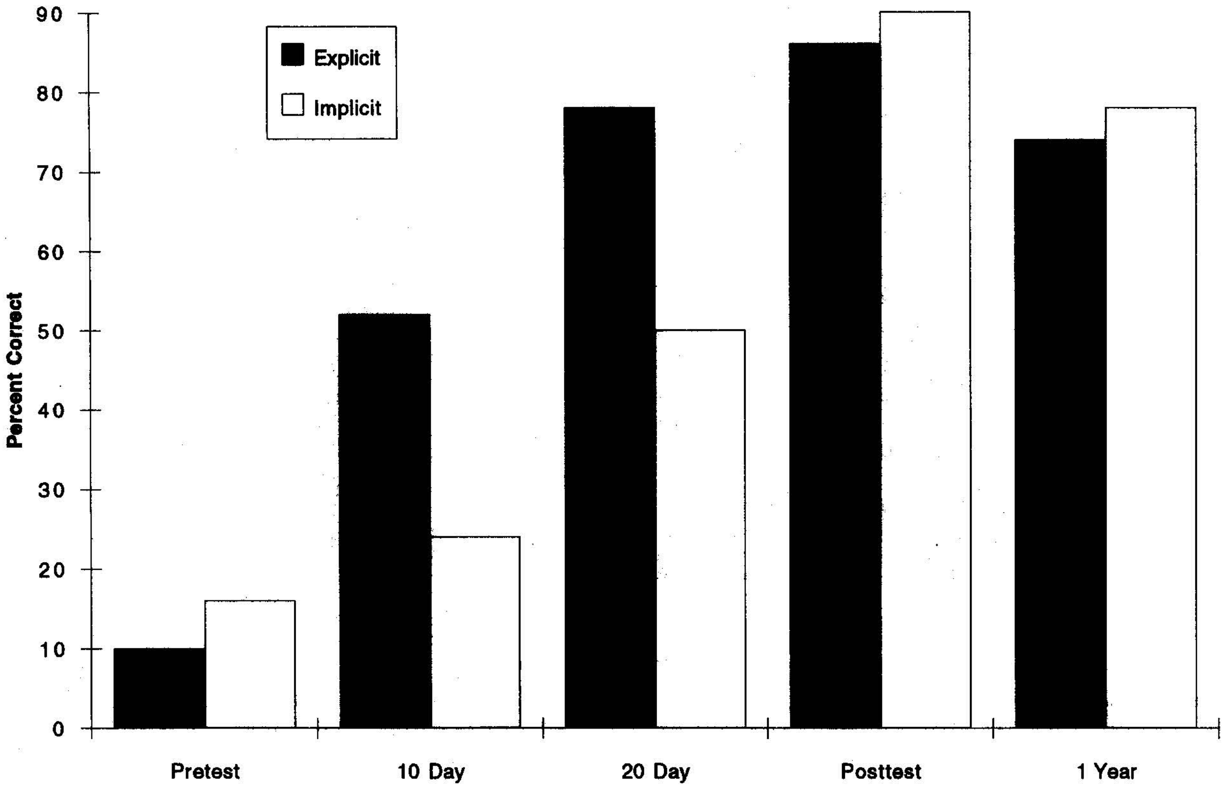
Note. From "Guided Discovery in a Community of Learners" (p. 249), by A. L. Brown and J. C. Campione, 1994, in K. McGilly (Ed.), *Classroom Lessons: Integrating Cognitive Theory and Classroom Practice,* Cambridge, MA: MIT Press/Bradford Books. Copyright 1994 by MIT Press/Bradford Books. Reprinted with permission. Pre = pretest; post = posttest.

independent and group research on some subset of a topic of inquiry. Mastery of the entire topic is ultimately the responsibility of all members of the class. This requires that they share their expertise with their classmates so that all may have access to the entire topic. This sharing is further motivated by some consequential task or activity that demands that all students have learned about all aspects of the joint topic. This consequential task can be as traditional as a test or a quiz or some nontraditional activity such as designing a biopark to protect an endangered species. These three key activities—(a) research, (b) in order to share information, (c) in order to perform a consequential task—are overseen and coordinated by self-conscious reflection by all members of the community. In addition, the research–share–perform cycles of FCL cannot be carried out in a vacuum. The community relies on the fact that the participants are trying to understand deep disciplinary content. They are learning about something meaningful. As a concrete example of FCL, I discuss how children learn about environmental science.

Halfway through the year, the research process is well underway in a second-grade class. The big idea underlying the students' research is that of animal–habitat interdependence. Rarely do children choose to conduct research on a plant. Children do not identify with plants—after all, they are not alive; they just sit there (Gelman, 1990). Six research groups are formed and begin working concurrently. Their chosen subtopics are (a) defense mechanisms, (b) predator–prey relations, (c) protection from the elements, (d) reproductive strategies, (e) communication, and (f) food getting. There is, of course, overlap among the topics, but each group has a distinct agenda.

Each group has one piece of the puzzle it will need to perform the consequential task: to design an animal of the future that has evolved a solution to the six research groups' questions—reproductive strategies, protection from the elements, and so on. Opportunistically during the unit (of approximately 10 weeks), and always at the end of the unit, the students divide up into jigsaw (Aronson, 1978) teaching groups. Each teaching group consists of one designated member of each of the research groups. These designated members have the responsibility of teaching the remaining members of the group about their research topic in order to complete the consequential task, in this case to design an animal of the future. Thus, in each teaching group, the RT leader is an expert on the topic he or she leads. One child knows about predator–

Figure 3
Reciprocal-Teaching Groups' Improvement in Problem Solving by Analogy



prey relations, someone can talk wisely on the strengths and weaknesses of possible methods of communication, and so forth. All pieces are needed to complete the puzzle, to design the "complete animal," hence jigsaw. Each jigsaw group designs an animal and presents it to the class and an array of visitors.

On the "Design an Animal of the Future" task, I scored the proportion of biological solutions mentioned and the constraining links between solutions. By constraining links I mean that if an animal were endowed with webbed feet to fit a swamplike environment, other related design features would follow, for example, has long legs and a beak, eats fish and waterborne insects, lays eggs, camouflages in reeds, that is, a coherent picture akin to something like a marsh bird. Children could, however, include no links; that is, all of their six solutions could be independent. And that is indeed what happened in my first iteration when only one FCL unit was practiced for three months (Brown, Campione, et al., in press). Although the children did provide five or six design solutions as required, those solutions were independent of each other.

To check whether this finding was typical developmentally, I then conducted a cross-sectional laboratory study where children not in FCL were asked to complete the same task after experience with only two similar tasks: design an animal to fit a specified habitat and design a habitat to fit a given unfamiliar animal. These data, taken from children in Grades 2, 4, 6, and 8, are shown in the left panel of Figure 9. These cross-sectional data confirmed my original microgenetic data: Second graders did not provide coherent, interrelated linkages in their design of animal survival mechanisms, whereas older children did so to a much greater extent.

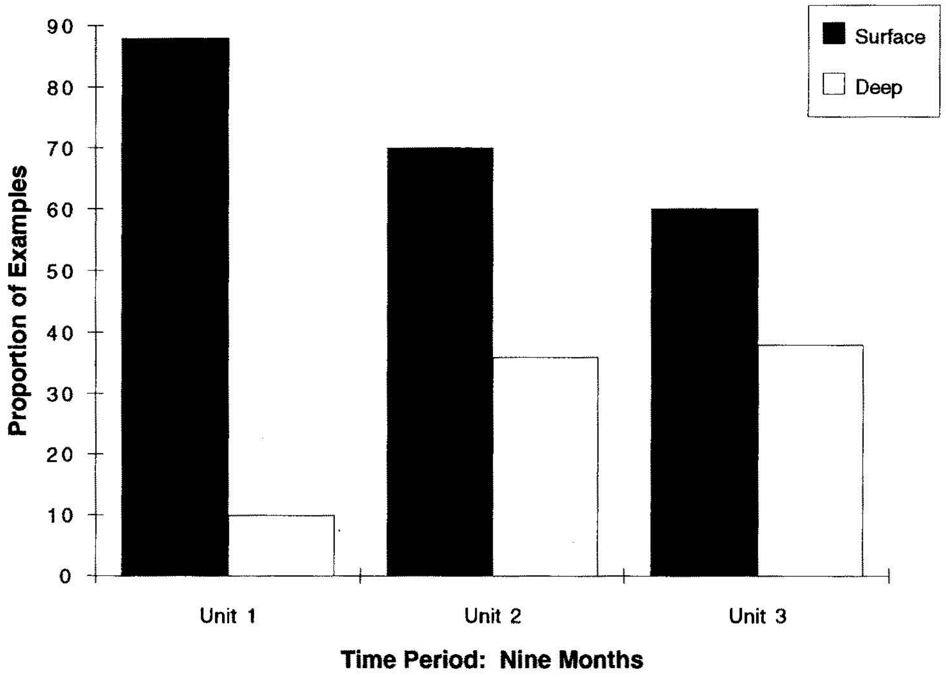
But I did not stop there. I conducted a yearlong intervention with second graders and found that they did manage some linkages, usually concerning the food chain and predator–prey relations. And, in the third replication, the class decided to design the habitats first and then the animal of the future to fit that habitat. This change resulted in a major improvement in the number of habitat-constrained linkages, with these second graders performing as well as sixth–eighth graders. These data are shown in the right panel of Figure 9.

Models of Metacognition and Expertise

On the Importance of Reflection and Discussion

In Figure 8, I show that the research–share–consequential task scheme is subsumed under the overarching concept of reflection. The FCL program, historically and inten-

Figure 4
Production of Analogies of 10-Year-Olds in Reciprocal-Teaching Discussions Within FCL Classrooms



Note. From "Design Experiments: Theoretical and Methodological Challenges in Creating Complex Interventions in Classroom Settings," by A. L. Brown, 1992, *The Journal of the Learning Sciences, 2,* p. 154. Copyright 1992 by Erlbaum. Reprinted with permission. FCL = Fostering Communities of Learners.

tionally, is a metacognitive environment. The classroom talk in FCL is largely metacognitive: "Do I understand?" "That doesn't make sense," "They [the audience] can't understand *X* without *Y*," and so forth.

Reflection and discussion are essential to the FCL classroom in which I explicitly aim to simulate the active exchange and reciprocity of a research seminar. FCL classrooms are intentionally designed to foster interpretive communities of discourse. FCL encourages newcomers to adopt the discourse structure, goals, values, and belief systems of a community of research practices. The FCL community relies on the development of a discourse genre in which constructive discussion, questioning, querying, and criticism are the mode rather than the exception. In time, these reflective activities become internalized as self-reflective practices and foster children's growing theories of learning (Brown et al., 1993).

How does one encourage this growth? Through adults, children, and computers! Adults and visiting experts in FCL classrooms provide welcome sources of domain-area expertise, but, most importantly, they also provide role models of thinking, planning, and reflective processes.

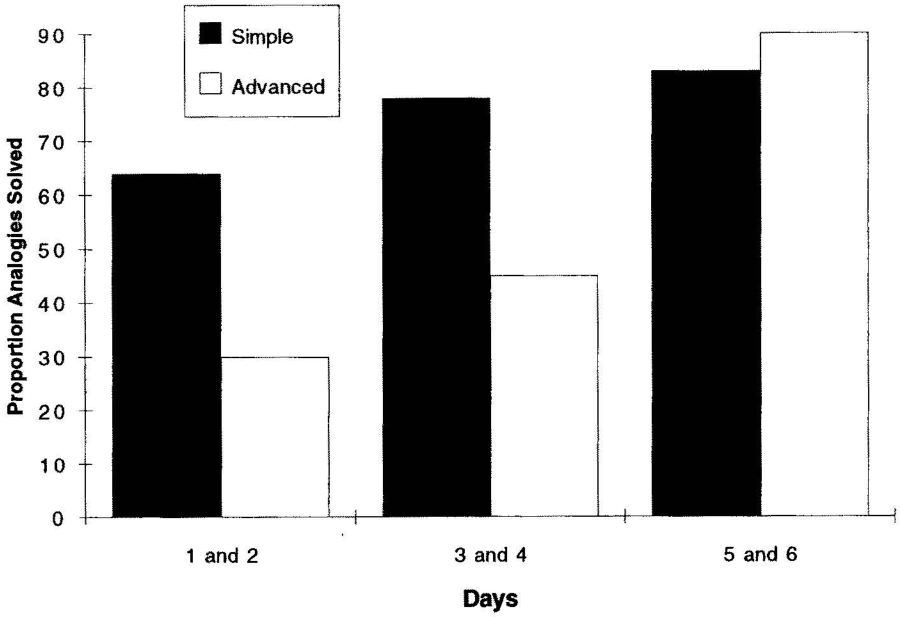
Adults as Role Models

Visiting experts and classroom teachers bring the whole class together for benchmark lessons that serve several functions. First, they serve to *introduce the class to the big ideas and deep principles* at the beginning of a unit. Second, they occur when the class is ready to *progress toward higher levels of abstraction.* The experts lead the students to look for higher order relations, encouraging the class to pool their knowledge in a novel conceptualization of the topic. For example, if the students have discovered the notion of energy and amount of food eaten, the experts might lead them toward the biological concept of metabolic rate. Third, the adults *model thinking and self-reflection* concerning how they would go about finding out about a topic or how they might reason with the information given or not given, as in the case of reasoning on the basis of incomplete information. Fourth, the adults continually ask students to *justify their opinions and support them with evidence,* to think of counterexamples to their rules, and so forth. Fifth, the adults ask the group to *summarize what is known and what still needs to be discovered.* Sixth, the adults lead the class in setting *new learning goals* to guide the next stage of inquiry.

Children Teaching Children

Children as well as adults enrich the system by contributing their particular expertise. Even after just one year in the program (and more so after two or three years), FCL students have considerable expertise concerning both the

Figure 5
Microgenetic Laboratory Study of 10-Year-Olds' Ability to Solve Story Problems by Analogy Across Days



domain itself and learning and teaching. Therefore, cross-age teaching becomes an important support for new learning. FCL uses cross-age teaching, both face-to-face and via electronic mail, and also provides older students as discussion leaders. Cross-age teaching not only increases the knowledge capital of the community but also provides students invaluable opportunities to talk about learning. Cross-age teaching gives students responsibility and purpose and reinforces collaborative structures throughout the community (Bruner, 1972).

On-line Consultation

Face-to-face communication is not the only way of building community and expertise; FCL classrooms have the benefit of wider experience via electronic mail. Teachers' and students' expectations concerning excellence, or what it means to learn and understand, may be limited if the only standards are local. Experts coaching via electronic mail provide FCL with an essential resource: freeing teachers from the sole burden of knowledge guardian and allowing the community to extend in ever widening circles of expertise.

Face-to-face and on-line experts are not merely providers of much needed information; they act as role models of thinking: wondering, querying, and making inferences on the basis of incomplete knowledge. Extending the learning community beyond the classroom walls to form virtual communities across time and space not only enriches the knowledge base available to students but also exposes them to models of reasoning and reflection about the learning process itself (Brown, Ellery, & Campione, in press).

Deep Disciplinary Content at a Developmentally Appropriate Level

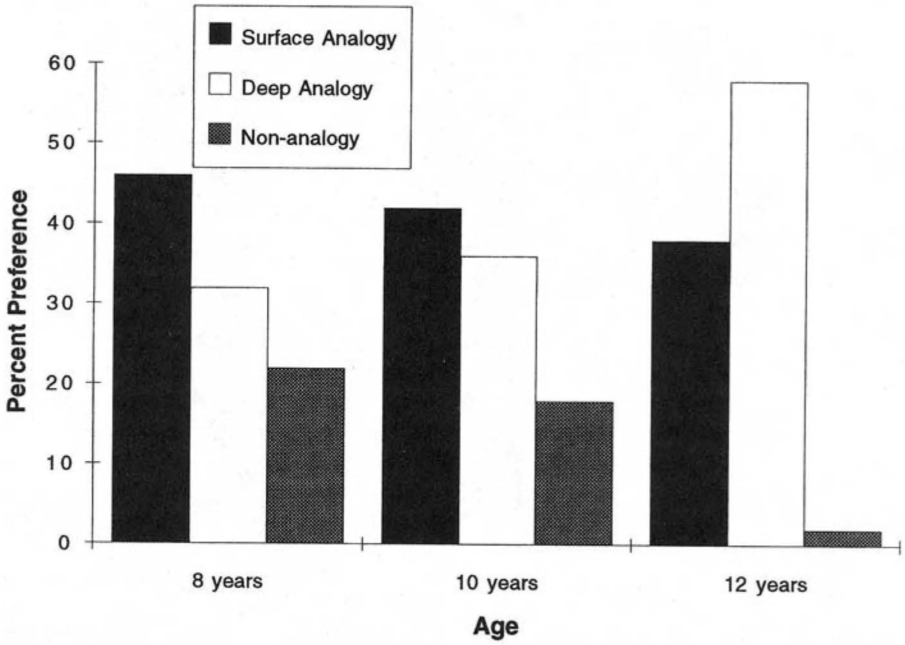
Disciplinary Content

Although initially designed as a thinking curriculum, FCL has always relied heavily on disciplinary content units of sufficient rigor to sustain in-depth research over substantial periods of time. One cannot expect students to invest intellectual curiosity and disciplined inquiry on trivia. There must be a challenge; there must be room to explore, to delve deeply, to understand at ever deepening levels of complexity. Here I discuss the development of the environmental science content about which the children are asked to reason and reflect.

FCL does not involve a curriculum in the usual sense because the students are partially responsible for designing their own. The curriculum teams, consisting of psychologists, teachers, and domain-area experts, decide on central themes to be revisited over time. To support the "discovery" of these themes, the classrooms are rich with human resources, such as visiting experts, older tutors, and electronic mail. Ideally, classrooms are also provided with a selection of artifacts, hands-on experimental setups, books, videos, newspapers, periodicals, and so forth that the students can use in the service of their research.

A main tenet is that an FCL unit should lead students to conduct research, read, write, and think about a compelling deep theme at a developmentally appropriate level. It is precisely because the field knows something about the development of children's theories of biology that I initially selected the biological underpinnings of

Figure 6
Cross-Sectional Data on Children's Preference for Analogical Solutions Produced by Students in FCL Classrooms



Note. FCL = Fostering Communities of Learners.

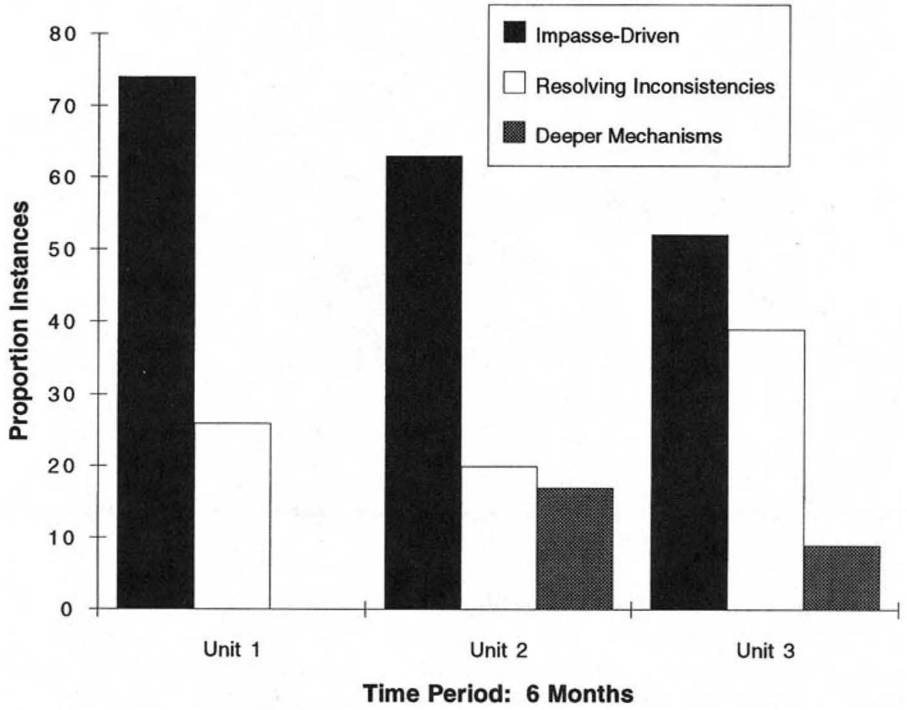
environmental science as a focus. The idea is to understand children's emergent theories about biology and lead them gradually toward deep principles of the discipline, such as interdependence, biodiversity, adaptation, and evolution.

Although I believe it to be somewhat idealistic to think of young children entering the community of practice of adult academic disciplines, awareness of the deep principles of academic disciplines enable the design teams to develop intellectual practices for young children that are stepping-stones to mature understanding, or at least are not glaringly inconsistent with the end goal. For example, in the domain of ecology and environmental science, I realize that contemporary understanding of the underlying biology would necessitate a ready familiarity with biochemistry and genetics that is perhaps not within the grasp of young children. Instead of watering down such content to a strange mixture of the biological and the biochemical, as textbooks for young children often do, I invite young students into the world of 19th-century naturalists—scientists such as Darwin who also lacked modern knowledge of biochemistry and genetics. The idea is that by the time students are introduced to contemporary disciplinary knowledge, they have developed a thirst for that knowledge, as indeed has been the case historically.

Practically speaking, this means that as students across grades revisit, for example, the topic of endangered species, they gradually reach toward increasingly sophisticated disciplinary understanding. I rely on establishing a *developmental corridor* within a school. Children remain in this corridor for several years, during which time they delve more deeply into the underlying principles of a domain. Second, 4th, 6th, and 8th graders may be working on similar topics: extinction, endangered species, rebounding and assisted populations, selective breeding, and so forth. All will be guided by the basic disciplinary principles of interdependence and adaptation, but different levels of sophistication will be expected at each age, a spiraling curriculum (Bruner, 1969), if you will. Topics are not just revisited willy-nilly at various ages at some unspecified level of sophistication, but each revisit is based on a deepening knowledge of that topic, critically dependent on past experience and on the developing knowledge base of the child. It matters what the underlying principles are at, say, kindergarten and Grade 2; it matters that the 6th-grade students have experienced the 4th-grade curriculum.

As a primary consumer of information about children's biological understandings, I use this information to help develop an age-sensitive curriculum. Unfortunately, my suppliers are still uncertain about the age at which biology emerges as an intuitive theory. Carey (1996) claimed that biology does not emerge as an autonomous domain until the end of the first decade of life. Inagaki and Hatano (1993) and Keil (1992) argued that preschool children have constructed an autonomous, in-

Figure 7
Production of Explanations in Jigsaw Discussions in FCL Classrooms Across Three Units



Note. FCL = Fostering Communities of Learners.

tuitive biological theory. Wellman and Gelman (1992) are agnostic as to whether preschool children have constructed biology as an intuitive theory.

Whether one wants to call it theory, there is agreement that young children can reason at a primitive level about specific causal mechanisms: for example, maturational growth, inheritance of physical properties, and disease transmission (Keil, 1994; Wellman & Gelman, 1992). And it seems safe, despite the controversy, to grant the six-year-old child with knowledge of causal agents (essences, innards, mechanical causality, etc.), in which case I can build on this reasoning to develop an educational corridor.

A similar developmental guideline governs my approach to reasoning within the domain. For example, initially I capitalize on functional and teleological reasoning (Keil, 1992) and an overreliance on mechanistic causality in general, but then I press for an increasingly more sophisticated consideration of variability, uncertainty, probability, and chance. Personification as analogy is a powerful, if limited, reasoning strategy used by young children (and by adults, for that matter). It supports inductive reasoning and helps children distinguish between biological kinds and artifacts. I allow children to reason on this basis, putting off until later discussion of the limitations of this way of thinking.

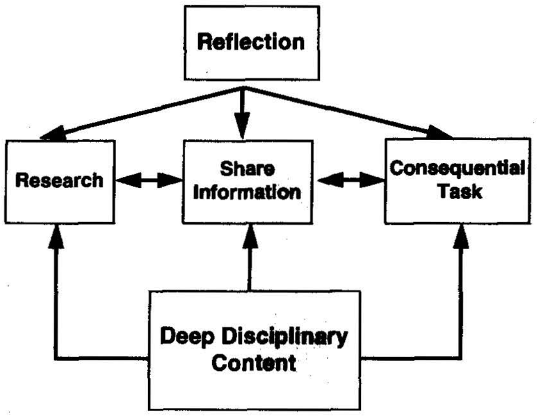
Moving Target

By deliberately aligning instruction to children's developing theories, I face a theoretical and practical issue about developmental sensitivity. Will 10-year-olds with prior experience in the program be capable of acquiring and using domain knowledge of considerably greater complexity than will 10-year-olds in the program for the first time? To the degree that FCL is successful, I should be mapping a moving target. Of considerable theoretical interest to developmental psychologists are answers to the following question: Which forms of understanding are eminently teachable and which are immutable in the face of carefully tailored instruction?

Developmental Trajectories

Although FCL has made considerable headway at aligning an understanding of children's growing biological knowledge and the design of a biology curriculum for grade school children, the field has far to go. Quite simply, a great deal more research is needed in both domains. Ideally, one needs to understand a developmental trajectory that grows in stepping-stones toward mature thinking that would fill in the gaps of the schematic shown in Figure 10. Beginning with knowledge of the early precocity of children as they enter preschool (in biology this would include form–function reasoning;

Figure 8
Schematic Representation of the Basic System of Activities Underlying FCL Practices



Note. From "Psychological Learning Theory and the Design of Innovative Learning Environments: On Procedures, Principles, and Systems" (p. 293), by A. L. Brown and J. C. Campione, 1996, in L. Schauble and R. Glaser (Eds.), *Contributions of Instructional Innovation to Understanding Learning,* Hillsdale, NJ: Erlbaum. Copyright 1996 by Erlbaum. Reprinted with permission. FCL = Fostering Communities of Learners.

differentiation between animate and inanimate, however shaky; a reasonable understanding of animal behavior, particularly if the animal shares human characteristics, etc.). One can build on this early knowledge by extending and refining it and at the same time concentrating on suspected problems of interpretation, for example, the difference between dead in the biological sense and never alive in the sense of artifacts. Plants are alive too, a notion somewhat alien to first graders.

Implicit theories get one going and almost definitely form the basis of everyday concepts and plausible reasoning biases, such as those studied by Tversky and Kahneman (1974), and Bartlett (1958) for that matter. But they can get in the way of formal reasoning that demands theory revision and radical conceptual change, which take time (Carey, 1985). Schools came into existence to foster formal reasoning because *it is hard* and often involves abandoning naive theories for scientific ones. These are the blocks to learning shown in the schematic in Figure 10. Gelman and Williams (in press) think that the concept of a rational number is such a block because it does not build on the early implicit theories of number. Statistical notions such as sample versus population, randomness, and probability appear to be equally problematic for the

Figure 9
Cross-Sectional (Left) and Microgenetic (Right) Data on the Number of Coherent Connections Between Invented Solutions in the Design of an Animal of the Future

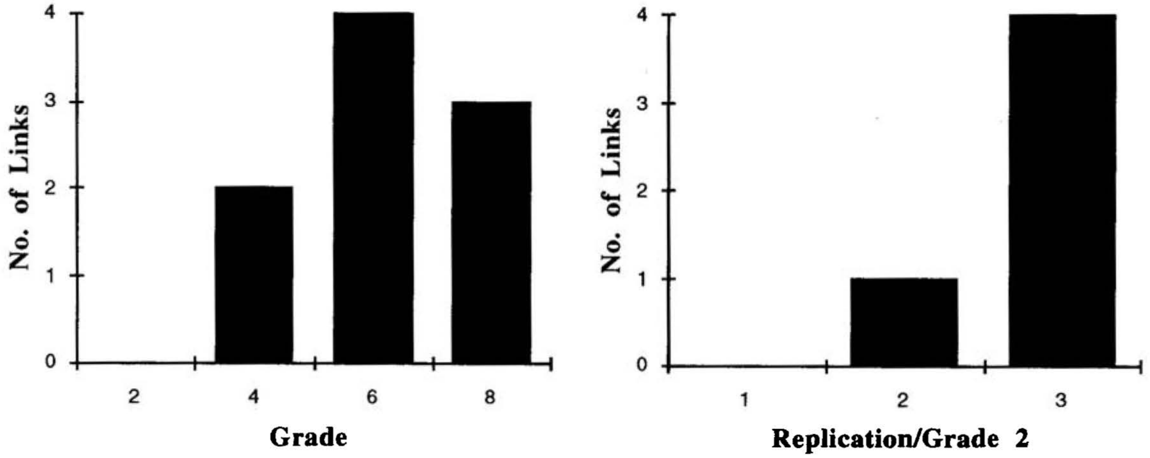
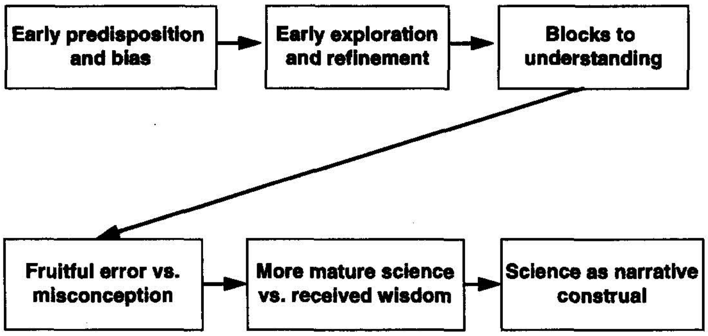


Figure 10
Idealized Developmental Corridor for the Design of Science Instruction



development of biological thought. One needs to recognize children's conceptions that are fruitful errors—ones that are not mature understandings but if carefully harnessed will lead toward more mature understanding. Fruitful errors are distinct from misconceptions, which lead in the wrong direction and will impede the growth of scientific thinking unless they are replaced. Finally, the field needs to look at the hallmarks of the mature science as received wisdom undergoing change, to a relativist position that adds the essential notion of narrative invention (Bruner, 1996; Medawar, 1982), to a student's understanding of science.

The field needs to understand such a trajectory in science *and* in the student's understanding of learning and reasoning about science, the child's epistemology, if you will. The field of developmental psychology is moving slowly but surely in that direction. This agenda will go a long way toward expanding on Vygotsky's (1978) notions of everyday versus scientific concepts and Piaget's (1978) conceptions of success and understanding and the epigenesis of formal operational thought. It will take thoughtful collaboration between domain-area specialists, science educators, psychologists, grade school teachers, and, yes, even students for us to reach these desired goals.

First Principles of Learning

Guiding the design of FCL is a set of learning principles that are addressed in detail elsewhere (Brown, 1995; Brown & Campione, 1994, 1996). Here I mention a subset that follows from Bruner's (1996) description quoted in the first paragraph of this article and the schematic summary of FCL shown in Figure 8.

Agency

FCL is intentionally designed to be an environment that emphasizes the active strategic nature of learning. Consistently, as teachers, students, and researchers, children routinely engage in a search for understanding and effort after meaning.

Reflection

Effective learners operate best when they have insight into their own strengths and weaknesses and access to their own repertoires of strategies for learning. For the past 20 years or so, this type of knowledge and control over thinking has been termed *metacognition.* Again, FCL is historically and intentionally a metacognitive environment with an atmosphere of wondering, querying, and worrying about knowledge. All actors in the arena are engaged in reflective practices (most of the time or some of the time!). Initially, young learners are trapped into these thinking activities through such participant structures as RT and jigsaw, where everyone must think aloud, thus making the invisible visible (Brown, 1980). But over time, it becomes second nature to appreciate good questions and to critically evaluate answers that are themselves partially correct and in need of revision.

Collaboration

In FCL, collaboration is necessary for survival. Students must share, as each member is privy to only part of the puzzle. Expertise is deliberately distributed (Brown et al., 1993) but is also the natural result of students majoring in different arenas of knowledge. Learning and teaching depend heavily on creating, sustaining, and expanding a community of research practice. Members of the community are critically dependent on each other. No one is an island; no one knows it all; collaborative learning is necessary for survival. This interdependence promotes an atmosphere of joint responsibility, mutual respect, and a sense of personal and group identity.

Culture

A culture of learning, negotiating, sharing, and producing work that is displayed to others is the backbone of FCL. FCL involves multiple ways into membership (Lave & Wenger, 1991), shared mores of behavior, and ways of community building. Differences are legitimized and used for the common good. The culture of FCL fosters change by encouraging newcomers to adopt the discourse structure, goals, values, and belief systems of the community. Ideas seeded in discussion migrate throughout the community via mutual appropriation and negotiated meaning. These classrooms are intentionally designed to foster interpretive communities that afford multiple roles and multiple voices (Bakhtin, 1986) and the active exchange and reciprocity of a seminar.

Deep Disciplinary Content

It is axiomatic in FCL that one cannot think deeply about trivia; one cannot think in a vacuum. Therefore, FCL helps students to reason at the upper bounds of their capability about serious scientific issues. They must support their reasoning by research, by seeking advice from others more expert than they, and by presenting the fruits of their work in exhibitions modeled after the displays made by working scientists.

Developmental Corridors

It is essential to the philosophy of FCL that students be engaged in research in an area of inquiry that is based on deep disciplinary understanding and that follows a developmental trajectory based on what is known about children's developing understanding within that domain. I argue that those who design learning environments for children should be primary consumers of research on children's learning in the domains they wish to foster. Only by so doing can we capitalize on students' need to know about certain phenomena at critical times, surely the greatest motivator for deep and lasting learning about serious matters.

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