
PERSPECTIVES ON SOCIALLY SHARED COGNITION

E D I T E D

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CHAPTER 11

CHARACTERIZING SUPPORTING ENVIRONMENTS FOR COGNITIVE DEVELOPMENT: LESSONS FROM CHILDREN IN A MUSEUM

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INTRODUCTION

There can be no doubt about it: Cognitive development must take place in the context of supporting environments, be these of the social, cultural, or natural world. But how should we characterize these environments? The standard account—that the more frequently novices are offered or exposed to inputs that we want them to learn about, the more likely they are to learn about them—runs into trouble as soon as we acknowledge that the young are active participants in their own cognitive development. Under this assumption, what counts as relevant is governed as much by what the young bring to the situation as by what we think.

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Put differently, if we allow learners to contribute to the definition of relevant inputs, we no longer control the definition of relevance. Consequently, it follows that “*learner*” and “*teacher*” need not share the same interpretation of a given input. And young learners do not necessarily agree with our judgment that the same input is being offered on two different occasions. In short, a constructivist theory of mind forces us to reconsider both the nature of relevant inputs and the role of frequency in a constructivist theory of supporting environments.

Our efforts to create museum environments that foster informal learning about mathematics and physics underscore the above points. A comparison of our exhibits with others at the same museum offers clues as to how the young can both be served by knowledgeable others—either adults or peers—and actively select and define what they view as relevant inputs.

WANTED: A CONSTRUCTIVIST THEORY OF SUPPORTING ENVIRONMENTS

Within the Empiricist tradition, there is one criterion for what counts as relevant data for a concept: The sources of that concept must be traceable back to sensory inputs. Social and physical stimuli do not differ in principle. If it turns out that social stimuli are more effective, this is because they are more readily sensed, offer richer bundles of sensory inputs, and/or are more likely to meet the requirements of the laws of association, but not because they are social per se.

Locke concluded that the blind could not learn visual concepts or terms because they cannot detect the sensations generated by the presumed relevant source, a skilled knower and speaker pointing to pertinent novel objects and actions. It turns out that the facts do not square with our Lockean intuitions. Landau and Gleitman (1985) report that acquisition of syntax, early vocabulary, and the functional uses of language in congenitally blind children can be remarkably like the acquisition of the same abilities in normal, sighted children. For example, Kelli, one of their young subjects, would hold up an object when told to “Let Mommy see the car” and hide an object when told to “Make it so Mommy can’t see the car.” She also turned around when asked to “Let me see your back,” but not when asked to “Let me see your front.” Kelli surely had to learn the meaning of *see*; she was not born knowing the English correspondence to this particular sound, anymore than a Spanish child is born knowing that *si* means *yes*.

Structures of Mind Look for Structured Patterns of Input

The Landau and Gleitman data are reinforced by findings that deaf children do learn to produce and comprehend language if they are allowed to reveal this

capacity through their hands (Newport, 1980). What kinds of supporting inputs serve learning in these cases? They have to be structured patterns of data, as opposed to punctate sensations, patterns that can be characterized with reference to grammatical categories. For example, Landau and Gleitman (1985) show that even minimal knowledge of syntactic patterns can begin to render unfamiliar verbs meaningful. Young children can use their nascent knowledge of syntax to find inputs that feed further development of their language. See Pinker (1989) for more on this point.

Within a constructivist framework, the foregoing can be recast as follows: Young learners are sometimes more expert than are knowledgeable individuals at defining supporting environments for learning. Despite their novice status as knowers of the target language, they are "experts" on the nature of the relevant inputs for language learning because they bring structured knowledge to the flow of speech (or hand patterns) they encounter. Such knowledge, no matter how skeletal, serves to focus attention on the class of inputs that share structural characteristics with it. The environment still must provide these data if children are to learn. Because adults are fluent users of the language, they cannot help but provide the necessary linguistic environment for children acquiring language, but adults need not know what is relevant for language learning, nor need they work at "teaching" the language.

The proposal that young language learners can make guesses as to which inputs are relevant, allowing that they have nascent structures of knowledge, is related to our contention that initial domain-specific skeletal principles serve cognitive development. Given the child's active tendencies to apply whatever structures are available, no matter how skeletal or devoid of flesh these might be, these structures can still serve to start children down paths of learning that adults, too, pursued as children. As a result, although our young start out knowing almost nothing, they have reason to traverse some common paths of learning. Additionally, these skeletal structures serve as memory organizing files, making it possible to keep learned bits together in memory before they are understood to be related. See Gelman (1990) for further development of these rational-constructivist ideas.

Matters Piagetian

The idea that children are sometimes "experts" on the nature of relevant inputs is consistent with Piagetian theory, wherein children are assumed to be actively involved in seeking out and even generating data that nourish the development of their cognitive schema. Karmiloff-Smith and her colleagues (e.g., Karmiloff-Smith & Inhelder, 1974-1975) detailed the way children's tendencies to apply their implicit "theories" lead them to explore problem spaces and generate, on their own, conditions for further learning. Note that this kind of view of the environment does not assign a special role to social supports for cognitive development. It does not matter whether children find intellectual nourishment in

their physical, social, or own mental world, as long as they find some suitable nourishments to assimilate to the cognitive structures they possess. Piaget would insist that whatever inputs children use as nourishing supports for their conceptual development must be characterized in structural terms.

Piaget had little to say about the relationship among social, physical, mental, and cultural supports for cognitive development. And he denied that language, as opposed to other representational formats, has a special status as a medium of thought development (Furth, 1966). In fact, the notion that the content of a domain influences the degree to which children will master it is, in a way, inconsistent with Piaget's theory, which holds that development involves the acquisition of general logical structures of mind—ones that apply across a wide range of disparate tasks and domains. But there is considerable evidence that different domains of knowledge are not all equal in form. We cannot assume that relevant inputs for cognitive development are best characterized in logical terms. Still, Piaget did suggest that peer interactions might function best to engender development, possibly because a peer is more likely to share related assumptions about the key features of an environment at a given point in development.

Matters Vygotskian

Vygotsky, and those who share a commitment to his and his colleagues' views on development, also grant the child an active role in cognitive development (e.g., Saxe, Guberman, & Gearhart, 1987). In contrast to the Piagetian position, Vygotsky and his followers are concerned about different kinds of inputs, be these cast as everyday versus scientific, or as physical, social, cultural, linguistic, and symbolic.

Of special interest to us is the pairing of a constructivist position with the assumption that adults and other knowledgeable persons lead in creating relevant inputs (e.g., Rogoff & Wertsch, 1984). Adults, or others who possess knowledge of their culture's goods, are seen as guides and nurturers of children's constructivist tendencies. The younger the children, the more this is the case, presumably because they know less and thus are more in need of having their constructivist proclivities nudged in the right directions.

In treating adults (or others who know more than a novice) as agents of knowledge socialization, theorists must consider two issues. First, we must question whether it can be assumed that such individuals have both the presumed levels of motivation and the competence required for such a role. To be sure, there are studies wherein knowledgeable adults and peers function as described (e.g., Saxe et al., 1987; other chapters in this volume). However, families' ideas on how to divide household labor do not always entail the view that adults are all-knowing, all-benevolent, and suitably motivated (e.g., Goodnow, 1990). So the question remains open about the critical role of adults.

A second important issue is that the assumption about the critical role of adults may not be consistent with a constructivist theory of mind. To hold that the environment can be defined and offered by those already in the know is to flirt with (not necessarily intentionally) a variant of the Empiricist theory of the environment. To get around this potential pitfall, it is necessary to confront an apparent contradiction. If young children share no knowledge with adults from the outset, expert and novice need not converge on the same definition of what is a relevant environment. But it is clear that cultures do transmit their knowledge from one generation to the next.

If we allow some overlap in some knowledge domains between adults and young children, we can begin to eliminate the contradiction raised above. This is one reason we adopted a rational-constructivist position. But this move on its own is not enough. We still need to characterize environments that can support the growth of these early skeletons of knowledge, can explain how children learn about their Cultural Unconscious, and are consistent with the fact that children can learn new concepts, ones that presumably go beyond the range of initial skeletal principles. Our attempts to deal with these lacunae build on what we found when we looked at how exhibits in a museum for young children influence the kind and amount of child-adult interactions, especially in terms of the matter of informal "teaching." We conclude that there are multiple environmental routes to knowledge acquisition, not all of which are equally suited to all kinds of learning.

LESSONS FROM A MUSEUM

Some Background Details

Our study of museum learning was conducted at the Please Touch Museum (PTM) in downtown Philadelphia. It serves a target population of children seven years of age or younger, which means its target clientele must be accompanied by responsible adults.

The museum attracts a fairly mixed racial and socioeconomic sample of school groups and families and operates at capacity about 50% of the time, receiving about 140,000 visitors per year. A somewhat high (\$4.50 per individual) entrance fee is offset by memberships or scholarships and passes to low-income groups and families. PTM is located near two science museums (The Franklin Institute and the Academy of Natural Sciences), and families can use package tickets to visit all three museums on the same day.

PTM offers both special and permanent exhibits. There are benches and chairs throughout the museum. All floors at exhibit areas are carpeted, and visitors often sit or lie on the floor. Over the four years that we have been observing, exhibit areas have featured a grocery store, a doctor's office, an accountant's

office, various forms of transportation, science materials, a television studio, an Indian village, a puzzle corner, a live-animal arena, areas to dress up in costumes and masks and put on stage shows, puppet shows, and a circus. There have been special exhibits on musical instruments, number concepts, scientific concepts, different cultures, block collections, toys from past decades (some from previous centuries), and fantasy. All exhibits are designed to encourage interactions, both between members of a family and with the props. The museum also has a bookstore, runs symposia, conducts workshops for children and adults, and houses significant archival materials.

The Museum as a Natural Research Setting

PTM affords a rare research opportunity. One can observe adult-child interactions without asking caretakers to be with their children. The sense that the museum is like someone's living room or a "safe park" in a large downtown city area surely contributes to its popularity, as does the fact that adults and children move around and choose activities freely, *either as a family or not*.

To illustrate why we think it is important to observe how adults interact with young children without asking them to do so, consider the difference between observing parent-child interactions as a participant-observer in a museum and observing parent-child interactions as a guest-observer in a home. In the latter case, assuming that researchers succeed at encouraging the pair to be as natural as possible, the parent still knows she or he is in at least two roles: parent and participant in a study of parent-child interactions. On the assumption that adults are cooperative participants in the study, we should expect them to render their most competent performance (Orne, 1962). Therefore, such studies can inform us about baseline levels of competence. But to determine the extent to which this competence generalizes, studies run in different settings and under varied conditions are required.

Several investigators have observed successful interactions of turn-taking between a young child and a parent, in which the adults guided their young charges' efforts, for example, to work a puzzle (e.g., Wertsch & Stone, 1985). But what if the same child knew there was a cage containing a live rabbit behind her? What if the parent had a friend in the room and could sit and talk to the adult while the child played with the puzzle by herself? What if the adult would prefer to play with blocks and could wander off to do this while monitoring the child, who preferred to sit and play with the puzzle? Under these circumstances, the child might still succeed, might be at least as comfortable as when her parent does work closely with her, and might do her next puzzle more systematically (e.g., DeLoache, Sugarman, & Brown, 1985). How would we then characterize the adult's contribution to skill development?

These considerations led us to take advantage of PTM's willingness to allow us to be participant observers (see following discussion). We could step out of our usual research roles and *pass* (to use Goffman's term) as museum staff. The institution is such that children and adults encounter a wide choice of activities that afford opportunities for exploring and learning about new and unfamiliar things. In addition to these museum activities, we also know that such museums serve as places to meet friends, to get out of the rain, to watch other people, to have fun, to eat different foods, to snack on "junk," or to go when the family decides on an outing (e.g., Diamond, 1981).

The quality of PTM as a research site is enhanced by the fact that displays are designed to take into account children's viewpoints, abilities, and interests. For example, the counters in the "life-size" Grocery Store are 2 ft high and the mirrors are only 3 to 4 ft tall. Experts on early child development are consulted in developing exhibits, and children are observed using them. The goal is to encourage interaction with the materials and with other people. In short, PTM adheres to a constructivist philosophy, in addition to meeting some of our critical research design needs. It would have been hard to create a better setting ourselves.

Before starting our observations at PTM, we made regular visits, in part to get acquainted with the setting and in part to ease into our roles of participant-observers. At the museum we wore badges identifying us as museum staff (e.g., research advisor, docent, or intern), and we behaved accordingly. When we started to observe or tape, we used PTM permission procedures. When PTM collects its own data or sets up "photo opportunities," responsible adults are asked to sign consent forms that allow for research and educational use of any tapes, data, or related material. If permission is not forthcoming, the data are destroyed or simply not gathered. On those few occasions when we were asked what we were doing or whether we had special knowledge about the exhibits, we acknowledged our university connections. The rarity of such encounters adds to our confidence that visitors treated us as museum staff rather than special guests, such as celebrities, television crews, or newspaper reporters.

As described later in this chapter, PTM's cooperation and collaboration also made it possible for us to introduce exhibits that we designed.

Different Sites, Different Interaction Patterns

Just as the exhibits at the PTM varied in type, so too did the way visitors used them. Samples of interactions at the Grocery Store exhibit and the number exhibit (1-2-3 Go!) illustrate some of the differences.

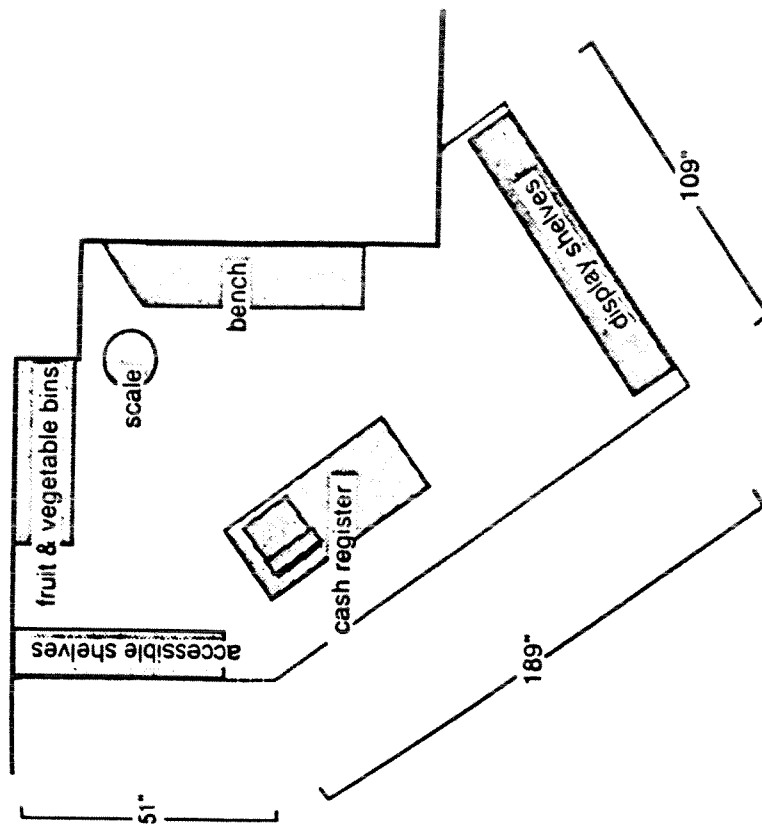


Figure 1 Floor plan of Grocery Store exhibit.

The Grocery Store: An everyday setting

In our culture, grocery stores are common everyday settings for children, especially young ones in the company of an adult. The Grocery Store at PTM, albeit close to life-size (Figure 1), is more like a neighborhood corner grocery than a supermarket. Still, the exhibit offers many of the familiar trappings one finds in both kinds of stores: shelves of food, boxed and canned goods, a scale, a checkout counter, and a cash register. The following excerpts from transcripts are based on recordings made with a flat microphone placed inconspicuously in the area.

Example 1 of grocery store talk

[Speakers were a mother and her 2½-year-old daughter]

Mother: Here's a shopping list. Look, what you have to do is find one of each picture. Tomato, lemon, pepper, corn, cucumber.

Child: I try it.

- Mother: Ohh, you're going to do it? Good girl. Why don't we put milk on your list? Let's go to the scale. We have to weigh it. Up, it weighs a quarter pound. How much? Hey, C—, you need a cucumber. You have a cucumber on your list.
- Child: I don't want a cucumber on my list!
- Mother: Well, I want a cucumber.
- Child: And I can buy carrots.
- Mother: First you have to put the food back, and I will help you. Here, put the carrots back where the pictures are, here. There's the picture of the carrots, so that's where the carrots go. Good, here's the other one, and the potato goes in there. Okay, here's a potato. Good girl. Here's an apple. Do you know where that goes?
- Child: No . . .
- Mother: Good girl. You put everything away. I'm proud of you. (*indistinguishable*) the shopping list.
- Child: Oh, you want to do the shopping?
- Child: I wanna do that.
- Mother: OK. OK, Miss, I would like 2 tomatoes. Would you ring up 2 tomatoes for me, please?
- Child: I want to ring up popcorn.
- Mother: I want popcorn, too. Thank you, that's a good idea. May I have popcorn?
- Child: Here's . . . shopping (*indistinguishable*)
- Mother: Thank you.
- Child: Here.
- Mother: Thank you.
- Child: Here.
- Mother: Thank you.
- Child: Popcorn.
- Mother: That's not popcorn. . . .

Example 2 of grocery store talk:

- [The speakers were a mother, father, and their 4-year-old daughter]
- Father: Are you going to get me some bananas? I need some bananas. Let me have some food. Can I have some Campbell's soup? What else? Carrots?
- Mother: Tuna. Get by the cash register.
- Father: Hop up there so Mom can take a picture of you. Work the money.
- Mother: Yeah, work the money.
- Father: Work the money.
- Mother: Let me see ya.
- Father: Coffee? What else? How 'bout some milk?
- Child: All right. . . .

Both of the above transcripts show that parents do more in this setting than lead their children through the script of grocery shopping. They also organize the activity, in one case by encouraging their child to sort the different kinds of food and match three-dimensional replicas of the food to pictures of these that appeared on the bins. We documented this tendency of adults to introduce and organize children's activity in this area for a pilot sample of seven children (between 2 and 6 years of age) and the adults with them. Behaviors of children and adults were coded in three categories: (a) prompting, requesting, or ordering another to do something; (b) responding to another's behavior (e.g., fulfilling a request, saying "thank you" when given something); and (c) behavior independent of another's behavior. Of all the behaviors coded, 45.5% were adults' prompting, requesting, or ordering children to do something. This was by far the most frequent type of adult behavior.

Such characteristics of the interaction fit with the idea that learning occurs in natural settings because adults help structure the input for their charges (Greenfield, 1984). But some features of the interaction hardly support the idea that the young contribute actively to their own learning goals and environments. Adults in the above excerpts were very little inclined to give their children control of the interaction. Instead, they seemed determined to control the flow of events. In the first example, the mother seemed as much concerned that her daughter do the proper thing for the setting as that she have fun playing Grocery Store. When the list had a cucumber on it, the child had to get a cucumber. Before the child could buy a carrot, she had to put the carrot (plus lots of other vegetables) back where the mother thought it belonged. It remains to be determined whether such adult control served to teach.

Also of interest is the fact that talk about money, weighing, pricing, and so forth, was only at the most general level. In fact, adults said things that are decidedly inappropriate; one does not usually weigh cartons of milk, let alone talk about them in units such as pounds. If learning about quantitative matters did occur in this setting, it did so in the face of rather noisy data. Such observations are consistent with Durkin, Shire, Riem, Crowther, and Rutter's (1986) report that young children receive messy and errorful counting inputs. These observations also raise the possibility that inputs for learning about number and other quantities are more variable than we have assumed. Our observations of the 1-2-3 Go! special exhibit at PTM support this conjecture.

The How Many Box in the 1-2-3 Go! exhibit

In 1986, PTM mounted a special exhibit on numerical concepts. The 1-2-3-Go! exhibit included displays to encourage children to count, order, classify, match, establish one-to-one correspondence, use quantitative vocabulary, estimate, and assess or generate the cardinal number of collections. The How Many Box was one of the displays meant to support the latter activity.

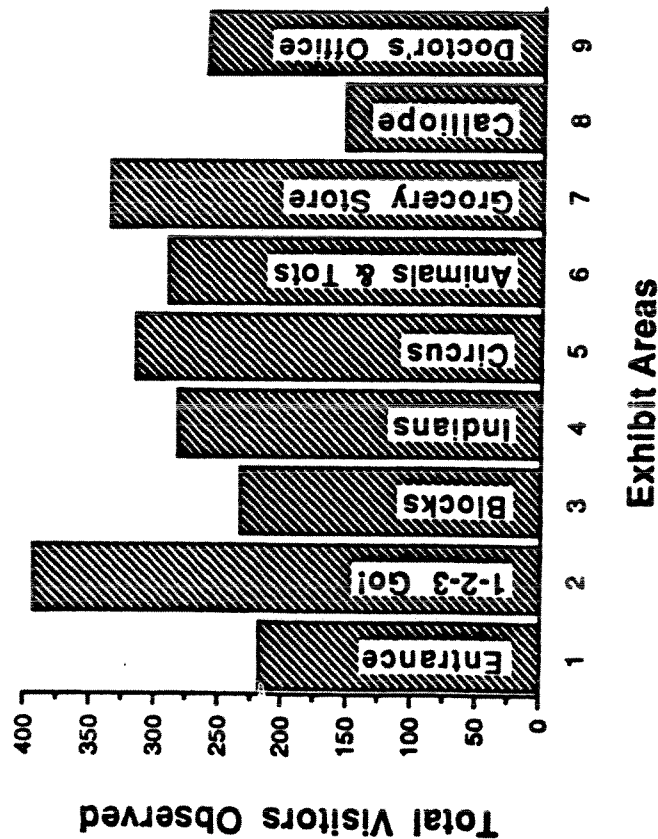


Figure 2 Distribution of visitors in different exhibit areas for observations collected from February to April, 1987.

To assess relative levels of interest in the 1-2-3-Go! exhibit, we regularly sampled the distribution of visitors at each exhibit area on the museum floor, keeping track of both the sex and age of those present during a sampling time (see Gelman & Massey, 1987 for more details). Our February to April 1987 samples of the total numbers of visitors in each of the museum areas listed in Figure 2 are typical of what we found. The 1-2-3-Go! exhibit was very popular, indeed about as popular as the Grocery Store.

Because such records showed that children and adults visited the number exhibits at the same time (Gelman & Massey, 1987), we went on to observe their interactions. Saxe et al. (1987) found that mothers who are asked to join their children in a number game are very likely to notice and then lead on from their children's mathematical goals. Children who experienced such interactions did better in the end than those who did not. The PTM setting allowed us to ask whether these tendencies generalize. For instance, do they appear when both participants have other things to do and/or do not think of themselves as cooperative participants in a research effort?

Our observations focused on the How Many Box, which was 3 ft high x 2 ft wide x 2 ft deep and had *HOW MANY* painted on each of its surfaces in large,

black letters. In addition it had six lift-up doors on each of its vertical faces. Underneath the doors were pictures of various collections (e.g., eggs in an egg carton, legs on a chair, wheels on a bike, headlights on a car). Writing on each door completed the "How Many" question for the particular displays covered by that door (e.g., how many "headlights on a car," "legs on a chair," or "apples in this picture").

For children to use this exhibit as the designers intended, adults *had* to read the signs to them. Almost all children were preliterate. Some might think to count on their own. But they could also open and close the doors, repeatedly bang one door up and down, name the pictures, and so forth. To our surprise, adults usually did not read the few words on the sign (Gelman & Massey, 1987). Of the 43 adults observed in one set of observations, only one third asked the "How Many" question and even fewer (19%) counted or encouraged the children to count. In fact, 30% of the adults simply stood or sat off to one side while the children lifted and shut doors, labeled items, and so forth. Like Saxe et al. (1987), we found that when an adult read the signs and counted or encouraged counting on the part of their charge, that child was more likely to count than were other children who did not encounter such support. But we have to emphasize that such interactions were rare and seldom lasted long enough to guarantee that a child reached the intended goal—to determine the cardinal value of a given set. Apparently, adults—who surely are able to interact so as to encourage their children's interest in number activities—do not always choose to do so.

Different Domains: Different Transmission Environments?

Saxe et al.'s (1987) findings make it clear that parents are able to serve as *competent* teachers of early number skills. But do they take this role often enough to make a decisive difference in their children's learning? Do they do it when there is no one asking them to? It is possible that parents may not want to teach these skills and, like elementary school teachers, they may think that "experts in math" should do so instead (Stodolsky, 1988).

Recall that, although parents in the Grocery Store were quick to lead their children through details of the pertinent script, some details received more attention than others. Talk about the grocery list and what went into which bin was very specific. In contrast, talk about such matters as unit weights and details about cost took place at a more general or even inappropriate level. Is this yet more evidence that parents assume that details about quantity are for others (e.g., schools) to deal with? A similar set of questions emerges when we consider the way physics materials are treated in the context of the museum.

Our early attendance counts showed that the few physics items, mainly involving gears and inclined planes, were not popular at PTM. We sometimes

saw a child stop to look and ask "What's this?", a question that usually was answered. But follow-up questions such as "How does it work?" typically led the adult to move on or redirect the child's attention to another exhibit. This contrasted dramatically with the kinds of interactions we saw between the same pairs in the Grocery Store, and struck us as rather odd. Surely the children knew less about mathematics and physics than grocery stores. Because the children were attracted to the former displays, one might even expect that adults would be more inclined to interact and "teach" at these. Given that just the opposite happened, it becomes necessary to consider the content of a domain as well as the situation in which adult-child interactions occur to understand how interactions between a knowledgeable individual and a novice serve the latter's cognitive development. These findings suggest that knowledgeable adults do not always engage in those activities that maximize the likelihood that their charges will learn about what they do not yet know.

When adults are in settings in which they can make choices, the degree to which they think of themselves as more or less competent to "teach" in a given domain probably influences the way they behave. Although we all have intuitive understandings in the math and science domains, often these understandings are not stateable, limited, or even wrong (McCloskey & Kargon, 1988). In contrast, scripts for the grocery store, taking a trolley, going to the doctor, and so forth are well known and understood (Schank & Abelson, 1977). Adults are masters of the everyday social and economic roles they play. Similarly, adults surely know the comparable setting-relevant vocabulary items that they "teach" young children, whereas they might not be as fluent with technical terms that are used in the math and physics domains. We live in a culture that assigns many different roles to adults. As members of this culture, we know whether or not a given activity is within our own purview, which activities are common to a large part of the culture, which are reserved for those with expertise, and so forth.

Knowledge about our everyday social institutions forms part of our common folk psychology and comes to be taken for granted (Bruner, 1989) and used to frame our explanations of how and why people interact in their sociocultural circle. Such kinds of interactions can and do go on without any discussion of how gravity influences the rate at which something falls down an inclined plane, or other scientific matters. True, discussions about mathematics or physics depend on fluency with such knowledge, but so do discussions about any specialized topic, be it economics, history, or literary criticism. Therefore, parents might be more concerned that their children master what every successful member of a group must know than that they master what parents think is specialized knowledge.

Additionally, the idea that specialized knowledge or language requires the participation of experts could itself contribute to the differences we have noted. Goodenough's (1987) account of how the Pulawait teach their young males to sail

provides some evidence for this conjecture. This kind of learning is not embedded in the everyday activities of the group. Instead, the young men are required to attend special instruction meetings to memorize the names and movements of the stars. Only those who do well are allowed to continue and take instruction on the open water.

In sum, there are reasons to question the extent to which parents think they *should* serve in the role of teacher of all things. Even if they are competent in certain domains of expertise, they might still think it is not their primary role to pass on such knowledge to their children. They may be decidedly unwilling to delegate the teaching of "proper" behavior in public places such as grocery stores, and at the same time very willing to leave to others matters of science and math. If adults do not want to serve as teacher when it comes to "school" subjects, we need to expand on accounts such as that of Saxe et al. (1987) of how children join the ranks of the knowledgeable. Our next section details one strategy we have used to aid our efforts in this regard. We ask whether we could encourage children to focus their constructivist tendencies to learn about science in a museum. That is, we took on the task of trying to create exhibits that would support learning about science, even if children used the exhibit on their own.

THE TRY IT GALLERY: A JOINT VENTURE

Some Preliminaries

Our early observations that math and science exhibits were either unpopular or not used as they were intended prompted us to enter into a joint venture with PTM to develop a new exhibit area, the Try It Gallery. We chose displays on the basis of findings about the abilities and interests of young children, for example, simple machines that do not require an understanding of gravity or an explicit ability to explain the relationship between two states of an object or an event (Bullock, Gelman, & Baillargeon, 1982). We specifically included features that children should be able to assimilate. For example, since we know that young children are good at making predictions about the effects of changing simple physical causal events, we chose to design a display that allowed them to make predictions and experiment with conditions that might influence their predictions. We also tried to avoid exhibits that would elicit talk of misconceptions (McCloskey & Kargon, 1988); neither we nor PTM staff saw a need to create conditions that could elicit erroneous adult input. The name "Try It Gallery" was chosen, in part, to indicate that visitors were invited to try to participate in the scientific process: to make predictions and perform tests, to classify according to scientific criteria, to apply numbers to different settings, and so forth. Additionally, it signaled an agreement between us and the museum to work together to build,

change, replace, or enhance particular displays in an effort to maximize the number of visitors sharing the designers' interpretation of the exhibits.

Given our argument that novices' interpretations of inputs do not necessarily converge with adults', PTM's agreement to this effect was especially important to us. We had every reason to expect to fail to accomplish our goal, which was, to generate conditions that children would interpret as we hoped they would. It is one thing to provide hands-on materials designed especially for young children and quite another to be sure that these objects will be used as intended. The objects themselves do not an experiment make. Blocks, tubes, balls, sticks, or pieces of wood serve a very large number of functions, depending on how one interprets them.

Trial One: Manipulatives Are Not Enough

From the start, the Try It Gallery met one important criterion of success. It was and continues to be one of the most popular areas in the museum. For example, our 1988 January through February counts of the total number of people in an area showed that it was the most popular exhibit of all. The Grocery Store and the adjoining Trolley Car area ranked second. Analyses of 19 counts on weekends and on a school holiday revealed that children and their parents were about equally likely to be in the area. This means that we can ask both whether the adults structured the children's use of particular exhibits and whether children interpreted them as designed. Our most detailed data on these questions came from an exhibit on motion, *The Racing Balls*, schematized in Figure 3.

The Racing Balls display

The exhibit consists of two identical large red cylinders wrapped with clear plastic tubing through which rubber balls can be rolled. The tubing wraps around one cylinder three times and around the other cylinder five times. This arrangement was chosen because it offers young children a way to generate an assessment or compare the amount of time it takes for the balls on each cylinder to travel through their respective tubes. By counting the loops in the tubing, a child could predict which ball would take longer or travel a greater distance. The tubing material was selected to minimize friction; similarly, we limited the grade of the fall to limit acceleration but make it possible for the balls to roll. To encourage preschoolers to predict and count the number of times the tubing wrapped around each cylinder, we placed a sign conspicuously on top of the cylinders in the exhibit. It suggested that visitors "race" two balls by putting one ball into the tubing at the top of each cylinder at the same time and seeing which arrived at the bottom first.

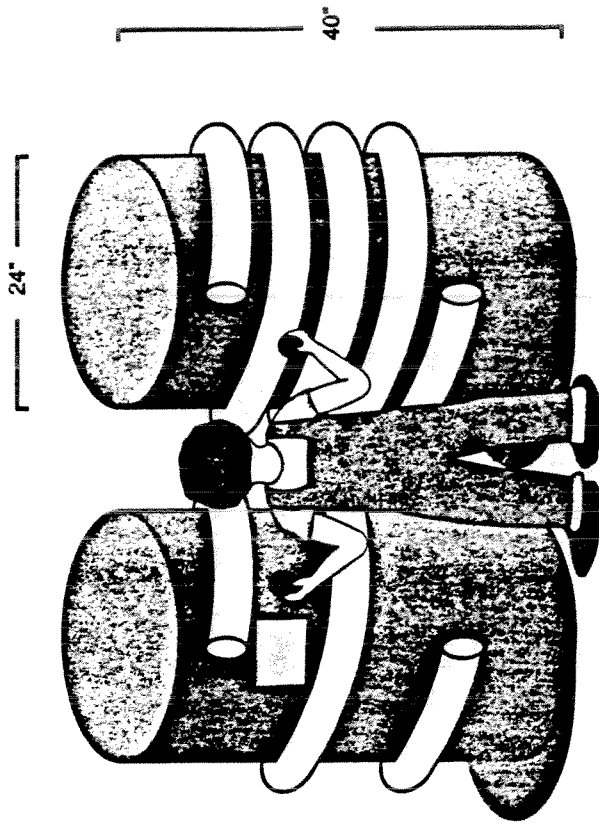


Figure 3 Schematic drawing of Racing Balls exhibit.

Preliminary findings. Our first effort to create an environment that would serve as an opportunity for young children to apply their existing scientific and mathematical knowledge to conditions that might expand their use of these was not successful. Although the Racing Balls were used a great deal, they were not used as we had hoped they would be. Adults rarely read the sign to their preliterate charges. Seldom did a child spontaneously make a comparison between the two cylinders. Perhaps worse yet, adults infrequently intervened to suggest this comparison to them. Instead, children tended to concentrate on one cylinder at a time, repeatedly putting a ball at the top of a tube, watching its progress through a tube, catching the ball, and putting it into the tube again and again. As we will see, adults' input at this exhibit was minimal. In some instances, they pointed out where the ball should have entered the tube, or they retrieved balls when they rolled away; otherwise, they sat on a nearby bench or leaned against the top of a drum or the closest wall.

Trial Two: Some Artifacts Speak for Themselves

Although it is known that adults do not usually read labels when in museums (e.g., Borun & Miller, 1980), it is an especially troublesome outcome when they fail to do so even when they are with preliterate children. The artifacts in the Try

It Gallery, unlike the boat and plane at a transportation exhibit, do not, on their own, afford the intended interpretation. Although children are inclined to take one look at a boat and get in it, they do not think to compare times of arrival of two moving objects. This situation led us to wonder what we could do to increase children's tendency to use our props as intended.

One straightforward way to do this is to tell children how to use the exhibit, which is what we hoped their adult companions would do when they read the "Race the Balls" sign on the top of each cylinder. Because parents neither read these signs nor talked about the ways to use the display, we decided to modify the exhibit to speak for itself.

Trial Three: A Decision to Show, as Well as Tell

Because our exhibit did not seem to interest the children in the possibility of predicting, comparing, and so forth, we decided to use a computerized script that would show and tell them to try such activities. We accomplished this by placing a Macintosh computer inside one of the cylinders that now had an opening in front for the screen (see Figure 3). In collaboration with MITECH Inc. and the design and education departments of PTM, we (particularly Massey and McManus) developed an audiovisual script designed to provide enough information to inform users about the goal of the exhibit and to encourage making predictions, testing predictions, and explaining the phenomenon.

As Figure 3 shows, the modified Racing Balls exhibit ended up with a computer screen and speaker placed at a child's level. These were activated when a sensor (under a rug) picked up the presence of a visitor at the exhibit. A cartoon-like black-and-white video illustration of a child at the exhibit then appeared on the screen, and at the same time a (digitized) female voice suggested that the child race the balls around the two cylinders to see which would reach the bottom first. The illustration showed a child placing one ball in each of the tubes that wrap around the cylinders. After an appropriate delay, the speaker asked which ball won and why. Again after a delay, the message and accompanying illustrations suggested counting the number of times the tubing wraps around each cylinder. Finally, it showed how the display would look if the tubes were unwrapped and pulled out straight to the side. It explained that the ball traveling through the 5-wrap tube has further to go and, therefore, takes longer.

The development of the computer's script was governed by two related principles. The first was that it would use the language of science. The second was that it should provide hints and clues in an order that suited a scientific inquiry. The idea was to engage constructivist tendencies but to leave to the users the choice of ways they then experimented with key variables.

Methods for data collection

Observations of visitors at the Racing Balls exhibit were collected at different times of day and different days of the week, both before and after the computer was added. Our previous studies indicated that it was important to sample across these different time periods because the number and kind of visitors to the museum varies with them. For example, school groups with relatively more children for the number of adults predominate on weekday mornings; entire families are common on weekends and holidays, when the museum is generally very crowded. Every child who approached the exhibit during an observation period became a target subject. Observations done during especially crowded times were videotaped and coded afterwards; otherwise, data were recorded with pencil and paper by one trained observer as described in the next paragraph. Adults accompanying children who approached the exhibit while it was being videotaped were asked for permission to videotape the child, using PTM's standard forms. We observed 163 children before the computer was added, and 104 children after the computer was in place. Table 1 shows the distribution by gender and approximate age and indicates the number of children accompanied by at least one adult.

We recorded our observations using forms like the one shown in Figure 4. The gender and estimated age of each target child, as well as anyone else present at the exhibit, were noted. A separate page was used to record each time a ball was put in a tube (or two balls were inserted simultaneously), and all pages for a given child were then put together to provide a record of the interactions occurring at the exhibit during the time that child was there. The characteristics of the target child and whoever else was present at the exhibit were indicated on the data sheets, and each exhibit-related activity was recorded, along with a code indicating who performed the activity. In addition, all verbalizations related to the exhibit were written down. For example, Figure 4 shows one of the data sheets for two children, a 5-year-old boy and a 3-year-old girl, who were at the exhibit with a male adult. While the girl held a ball up to the cylinder on the left and the boy held one up to the cylinder on the right, the adult said, "Ready, set, go," so they would place the balls in the tubes at the same time. When the first ball reached the bottom, the girl said (correctly) that she won, and the adult asked why the ball in the 5-wrap cylinder took longer. The boy then replied that it is because the tube is longer.

Effects of the computer

We present three kinds of "before and after" results. The first result is based on a general measure of ball-rolling tendencies, the remaining two on the extent to which visitors interacted with the exhibit as intended. Of these, one focuses on the rate at which children encountered examples of both balls starting together and rolling around the cylinders simultaneously. Unless this condition is met, it

Table 1

DISTRIBUTION OF CHILDREN BEFORE AND AFTER COMPUTER WAS ADDED AS A FUNCTION OF AGE, GENDER, AND PRESENCE OR ABSENCE OF AN ADULT

Characteristics of child	Less than 5 years (n = 22)		3 to 5 years (n = 120)		More than 5 years (n = 18)	
	Before computer					
Sex of child						
Male	16		71 ^a		12	
Female	6		47 ^a		9	
Presence of at least one adult						
With adult	21		93		18	
Without adult	1		27		3	

After computer

Sex of child						
Male	7		51		11	
Female	4		24		7	
Presence of at least one adult						
With adult	8		50		15	
Without adult	3		25		3	

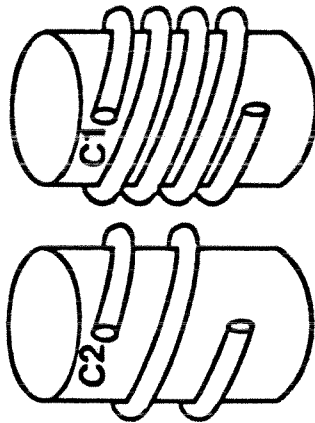
^aNumber of boys and girls in this group does not sum to the total *N* for the group because the gender of two children could not be determined.

is unlikely that they could go on to experiment as intended. The second focuses on whether or not talk at the exhibit was "scientific."

Mean number of ball-rolling events. The mean number of ball-rolling events performed or witnessed by target children serves as an index of the amount of physical engagement with the relevant materials. Often, more than one person was present at the exhibit at the same time. We counted a target child as having seen rolling balls, whether that child was responsible for the event or simply watched another who was. (Either activity can serve as input for learning.) We scored a ball-rolling event every time one ball rolled through one tube or two balls rolled simultaneously through both tubes. Efforts to push the ball up the tubing from the bottom were also scored as a ball-rolling instance.

A two-way (Presence vs. Absence of the Computer $\times$ Age) analysis of variance was performed on these data. Children were divided into three age groups

C1=male, 5
C2=female, 3
X=male adult



X: "ready, set, go."

C2: "I won!"

X: "why does this one take longer?"

C1: "because that's a longer tube."

Figure 4 Sample data sheet used for observations at Racing Balls exhibit.

on the basis of the observer's estimates of age: younger than 3 years, 3 to 5 years, and older than 5 years. There were no significant effects or interaction. Children experienced approximately the same number of ball-rolling events before and after the computer was installed ($M_s = 8.60$ and 10.25 , respectively). Interestingly, the mean number of ball-rolling events performed or witnessed did not vary significantly with age.

Experience with trials comparing balls simultaneously. Children have to witness or generate events in which the two balls start and roll around the cylinders simultaneously (hereafter referred to as *relevant comparison trials*) to get the point of the exhibit. Before the computer was in place, only 31% of the children received this kind of input. After the computer was in place, 76% of the children did. An analysis of variance (with Age and Computer Presence or Absence as between-subjects factors) of the mean number of times children performed or witnessed relevant comparison trials indicated that the computer introduced a reliable effect on this important variable, $F(1, 261) = 22.06, p < .001$. The means for children without and with the computer were .40 versus 2.17, respectively. There was also a main effect of age, $F(2, 216) = 5.49, p = .005$. The means for the three age groups in order of increasing age were .45, 1.97, and 1.43. Post hoc Tukey tests revealed that the mean for children in the 3-to-5-year age group was significantly greater ($p = .01$) than the mean for the children in the youngest age group.

Before the computer was placed in the exhibit, of the 31 children who were by themselves, only one saw a relevant comparison trial. Indeed, only 38% of the children with an adult saw at least one of these trials. After the computer was

in place, even when children were alone, they either watched or generated relevant comparison trials about two thirds (64.5%) of the time. Having an adult present in the context of the computer-altered version of the display had some effect beyond the computer itself. Under this condition, 80% of the children saw at least one of the relevant comparison trials. This is further documented by the outcome of a two-way analysis of variance (with the between-subjects factors of Computer Present or Absence and At Least One vs. No Adults) of the mean number of relevant comparison trials children saw. There were main effects for the computer, $F(1, 263) = 53.34, p < .001$, and for the presence of an adult, $F(1, 263) = 3.78, p = .053$. Without minimizing this effect of adults, it is still noteworthy that children did much better when they were on their own at the computerized exhibit than when they were with an adult at the noncomputerized one.

Effects of computer on kind of talk. Given that the computer did get visitors to compare balls rolling around the two cylinders at the same time, we finally can ask whether we succeeded. Did children (either with peers or adults) now experiment with the display so as to assess the effects of different variables on the rate at which the two balls got to the bottom of their tubes? Analyses of the kinds of talk that children and adults generated in the exhibit area reveal that they did.

Some of our observations were videotaped, and others were recorded by hand. Either way, we tried as much as possible to record and compile all exhibit-relevant comments made by visitors. We divided all of the talk samples into two categories, *Procedural* and *Scientific*. Procedural talk included commands and questions concerning the balls (e.g., get the ball, where's a ball?, put it in there), instructions regarding courtesy (e.g., wait, watch out, your turn), and comments such as "around and around" or "here it comes." An excerpt was scored as Scientific if it included predictions or statements about the critical event, that is which ball "won"; offered or asked for a prediction or explanation; counted the number of times the tube wrapped around the cylinder; talked about differences in time, rate, or length; or made comments related to coordinating simultaneous trials (e.g., ready, go!). The following excerpts illustrate some of the differences between these two kinds of talk. The first example was collected before the computer was put in the exhibit and consists mostly of procedural statements, especially imperatives.

Example 1 of computer study talk

[Adult and child (3 to 4 yrs), before computer was installed.]

(Adult does not read the sign and sits on bench; child stands in front of exhibit.)

Adult: Do you want to try it? Here's the ball. (Adult gives ball to child.) Put it in here. (Adult indicates top of tubing on 3-wrap cylinder.) Come here and wait. (Adult and child watch as ball rolls through tube.) It didn't make it. (Ball bounced onto floor at bottom rather than landing in the finish box at the end.) Try it again. (Child again places ball in tubing at top of 3-wrap cylinder.) It didn't make it again. Try one over here. (Adult gestures to 5-wrap cylinder.)

The following excerpt, recorded after the computer was operating, has much more talk about carrying out and interpreting the experiment. The kinds of comments made by this adult and child are typical of the kinds of things people talked about once the computer was in place.

Example 2 of computer study talk:

[Adult and child (6 yrs), after the computer was installed.]

(Child, while attending to the computer, first places one ball in the tubing around the 5-wrap cylinder, then a ball in each tube simultaneously, then one ball in the 5-wrap tube again. Adult watches.)

Adult: Do the balls go the same distance?

Child: Yes.

Adult: Why do you say this? Look at how many times [it] goes around here . . . watch. (Adult holds one ball at the 5-wrap tube while child holds the other at the 3-wrap tube.) Ready? Go! (They watch as the balls roll through the tubes.) Your ball got to the bottom first. Why do you think your ball won?

Child: Because my ball is faster.

Adult: All right, then let's switch balls. (They switch balls and repeat the procedure. Child is surprised.)

Child: Mine won again! (Adult has child sit down in front of cylinders to look at them.)

Adult: Which tube would be longer? (Child does not answer.) Try it again. (They each take a ball and start them simultaneously again, this time with the child at the 5-wrap cylinder and the adult at the 3-wrap cylinder.)

Separate analyses of variance were performed on the number of procedural verbalizations produced by children, the number of scientific verbalizations produced by children, the number of adult procedural verbalizations heard by each child, and the number of adult scientific verbalizations heard by each child. For each analysis, the Presence versus Absence of the Computer and Age (3 groups) served as independent variables. Results for each analysis follow.

For the procedural verbalizations produced by children, there was a marginal effect for the presence of the computer, $F(1, 261) = 3.64, p = .057$, with procedural verbalizations decreasing from a mean of .13 per child before the

computer was present to .004 per child after. There was no effect of age and no interaction.

For scientific verbalizations produced by children, there were main effects for both the presence of the computer, $F(1, 261) = 4.88, p = .03$, and age, $F(2, 261) = 5.03, p = .007$. Children produced significantly more scientific verbalizations with the computer present ($M = .50$) versus absent ($M = .14$). Scientific verbalizations increased with age, from a mean of 0 in the youngest group, to .32 in the middle group, to .64 in the oldest group. A post hoc Tukey test indicated that the difference between the oldest and youngest age groups was significant ($p = .01$).

Only children who were at the exhibit with at least one adult were included in the analysis of adult procedural verbalizations heard by children. For this analysis, there was a main effect for the presence of the computer, $F(1, 199) = 4.97, p = .027$, with children hearing a mean of 1.43 procedural comments from adults before the computer was installed and .63 after. There was also a main effect of age, $F(2, 199) = 3.43, p = .034$. The number of procedural comments children heard from adults decreased with age group from 1.59 for the youngest children, to 1.06 for the middle group, to .44 for the oldest children. The difference between the oldest and youngest age groups was significant (post hoc Tukey test, $p = .05$). Age and presence of the computer did not interact.

The analysis of adult scientific verbalizations heard by children also included only children with at least one adult companion. The only significant result in this analysis was a main effect for the presence of the computer, $F(1, 199) = 22.76, p < .0001$. There was an increase in the number of scientific statements or questions adults addressed to children, from a mean per child of .42 before the computer was installed to 2.05 after it was installed.

An additional analysis of variance was performed to see whether having an adult present had an effect on children's tendency to talk scientifically. The computer reliably increased scientific talk in adults. Did the presence of an adult independently affect scientific talk on the part of children at the display? An analysis of variance using Presence versus Absence of the Computer and Presence versus Absence of at Least One Adult as between-subjects factors indicates that adult presence does *not* significantly affect children's tendency to talk scientifically, $F(1, 263) = .97, p = .326$. Once again, there was a main effect for the presence of the computer, $F(1, 263) = 9.12, p = .003$, and there was no interaction.

Summing Up

Adding the computerized script to our display dramatically altered the quality of children's and adults' behavior. It led to increases in the number of times children

generated or saw two balls traveling around the cylinders simultaneously, it decreased the amount of procedural talk on the part of both children and adults, and it increased the amount of scientific talk observed for children and adults. In contrast, when left to their own devices, most adults did not attempt to demonstrate or "teach" at this exhibit. Although adults were more involved when the exhibit was supported by the computerized script, children could clearly proceed on their own or with other children. We still need to assess what children learned from this exhibit. Nevertheless, we finally achieved some success in our efforts to create an exhibit that children could interpret as intended, either on their own or with others.

We have argued that props in the environment need not constrain children's constructivist tendencies so that they follow the path we want them to. Even when we offer children signposts, we cannot be sure these will work. Our first effort to do this for one limited exhibit failed—despite the involvement of many kinds of relevant experts who worked an untold number of hours. In the end, it took still more people and a handsome commitment of funds to build a novel setting in which young children actively apply their armament of available science-relevant tools of inquiry and knowledge. We have made some genuine progress, but we are far from being able to specify in a systematic way what signposts will be effective for guiding conceptual development. Still, from this as well as the other work we have done at PTM, we have learned some lessons that apply to our goal. We turn to applying these lessons in our closing discussion of the nature of supporting environments for cognitive development, within a constructivist theory of mind.

CONCLUDING THEMES

The fact that constructivist theories grant young learners an active role in their own cognitive development means that novices and experts can disagree on the nature of relevant inputs. Given the difference between the knowledge of novices and of more mature learners, there must be times when our attention focuses on notably different inputs. Indeed, when novices benefit from domain-specific skeletal structures of knowledge, they can at times be better than adults at finding suitable inputs. Paradoxically, the young, who are novices in the sense of what they know, can sometimes be "experts" on the nature of relevant inputs. But how can one be an expert before mastering the material? Are there any principles that characterize these conditions?

Constructivist Principles of Supporting Environments

Principle One: Structures help define relevance

Constructivist theories are partial to structural accounts of knowledge. They assume that structures help individuals notice relevant data: Data that are consistent

with available structures are recognized as members of the equivalence class of relevant inputs because they share the characteristics outlined by the organizing principles of the structure. Given this, when novices do have nascent knowledge structures, they can find relevant inputs. Their proclivities to take advantage of any conceptual structures they have, however skeletal these might be, means that they cannot help but find relevant inputs. This is because the organizing principles of the structures offer clues to what inputs will nourish development of the requisite body of knowledge. In fact, by serving to define the equivalence class of inputs that can feed further development within their domain, these nascent structures carry with them ways for identifying novel relevant inputs. Nascent structures foster their own development, because they underlie the ability to recognize relevant data and store them in a coherent way. For this reason, the paradox presented above is no longer a paradox. Children are, in fact, experts on the topic of relevant inputs, because they are actively constructing reality with whatever structures they have. These structures help them find and assimilate samples of the very inputs that can nurture their further development. Because adults, too, once started along the same trajectory, the odds are high that we and the children will converge on shared knowledge bases.

Noisy data can be sorted. Our observations at the museum, especially regarding the kinds of mathematical inputs children encounter, lead us to the conclusion that adults sometimes offer children noisy or even inappropriate data. How do children sort through the noisy data to find the good in the bad? Once again, the active use of available structures can accomplish the work. Data are noisy, impoverished, bad, or irrelevant because they are not exemplars of the equivalence class of acceptable inputs. Because they do not share the requisite pattern, they are not candidates for assimilation by the structure(s) in question. Indeed, structures of mind need not even notice irrelevant or noisy data.

Experts need not know the nature of relevant input. If relevance is defined by the structure of a target domain, it seems at least as important that children have opportunities that maximize their chances of encountering examples of the target domains when they are trying to learn about these than that they have tutors who offer expert input at a given time. Language learning provides an especially good example of this possibility.

Children are surrounded with examples of language simply because expert speakers use their language a great deal of the time. Similarly, those who know the social rules of a group or a culture display this knowledge repeatedly in their everyday activities; by "doing what comes naturally," expert knowers perform generate examples of the pertinent data bases all the time.

Because there are always objects in the environment, and because there are always things that move on their own or do not, and so forth, there are domains for which the ubiquity condition applies. Hence, knowledgeable members of the community need not work on the creation of explicit lesson plans for novices to

learn much about the physical world. Whenever they use the knowledge they have, they cannot help but generate exemplars that become part of the environment. When a novice's structures are able to assimilate these exemplars, the pertinent data are likely to be present, with or without the intentional involvement of others at that moment.

Principle Two: Redundancy is a good thing

The foregoing discussion neither assumes nor denies that adults offer the young the best possible learning data. If adults are more competent than others to generate examples repeatedly, or take care to see that their charges are in the right places at about the right time in their developmental agenda, they might best serve as providers. But we have already seen that even when adults are competent tutors, they might not display their competence for some domains. Therefore, it would seem foolhardy to require our acquisition model to treat competent parents as necessary agents of cognitive development. Rather, we should say that the more generally available the pertinent data, the better, whether or not any adults choose to present these data, because, the wider their availability, the more likely it is that there will be times and conditions when the child's structures and the environment in question are mutually compatible. In a sense, this is one way to characterize the successful Racing Balls exhibit. Children can get their clues about what to do from the television, from watching other children, from interacting with their parents, or from experimenting on their own. No one condition need be better than another, unless we can prove that some kinds of information can only be conveyed in certain ways.

Some readers will recognize in the preceding conclusion a variant of a principle of *frequency*. We emphasize that this principle is not the same one that is assumed by association theorists. First, the requirement in our principle of frequency is that there be frequent encounters with any exemplars that are structurally equivalent, not that there be frequent encounters with the exact same stimulus. Second, the principle we are proposing does *not* function to foster the gradual build up of habit strengths. Instead, it serves a maximizing function: The more opportunities children have to encounter the class of inputs to be learned, the greater are their chances of this happening in a timely way, that is, when they are able to recognize and use these encounters as relevant input data. When exemplars from the class of potentially relevant inputs are omnipresent, the odds favor more novices finding at least some relevant data and, therefore, converging on the abilities or concepts to be learned.

Language acquisition is a case in point. We know that speakers from different cultures vary in the extent to which they simplify their talk to beginning language learners. Therefore, the rates at which they generate certain kinds of utterances vary from one language community to another. Still, children all over the world master the syntax of their language group at about the same age (Schieffelin &

Ochs, 1986), presumably because children all over the world hear many examples of the surface structure of the syntax that underlies these outputs.

The case of language acquisition helps us place the principle of frequency in a broader context, that of the *principle of redundancy*. People seldom generate the exact same utterance. Nevertheless, they do produce many acceptable sentences, ones that reveal the implicit knowledge of syntactic principles that fluent speakers share. Put differently, sentences are patterns of sound that are isomorphic exemplars of the structure in question. It does not matter whether two examples of relevant data are the same in surface detail or whether these are produced by the same model. What matters is that they share the same structural characteristics, whether or not those who generate equivalent sentence frames know that they do. This is why our account of why a child will find the relevant data does not require explicit knowledge on the part of those who have already achieved expert levels of competence.

Implications of the redundancy principle. This principle has both theoretical and practical consequences. From a practical point of view, we already know that some of our guesses about relevant data will be wrong. Hence, if we focus on but one variant of possible inputs, we put young learners at risk of not learning. We are better advised to offer redundant data sets, ones that offer multiple routes to the learners. This practice is a way to try to maximize the chances of a child's finding a route that adult and child both deem relevant.

On the theoretical side, the preceding section helps sharpen some of the questions addressed by this volume. For example, the question of whether cognitive development has to occur in a social setting can be stated as follows: Are adults more likely to present multiple, redundant examples of the target body of knowledge? Are there other ways to accomplish the same goal? In either case, what class of inputs is made available in one way that cannot be so generated under different conditions? Our work at PTM, especially the experimental effort to use technology to encourage attention to what we thought was relevant, serves as an example of how one might proceed here.

Lessons From the Museum About Environments

Division of labor might be the rule

Earlier, we showed that, even when adults might be effective generators of relevant inputs, they might not choose to serve in this role. This possibility means that we should expect variability to be the rule on the question of how well at-home observations of parent-child interactions generalize to other settings. In a culture like ours, adults might prefer to share or even divide the labor of knowledge transmission. It remains to be determined whether there are some tasks of knowledge transmission that parents prefer to give away and others that they claim as their own. But we already know from the PTM work that parents may not insist

on claiming all of the ones that they could. Domains that focus on school matters are not claimed as readily as are those that bear on everyday scripts, even when we know that the parents would succeed in transmitting the material in question.

It also remains to be determined how effective parents' inputs are compared with those offered by others. Saxe et al. (1987) report benefits, even over short-term periods, when mothers do work on number games with their children. Still, it would be good to have data comparing what children learn about such matters when working on their own or watching television, or when interacting with their peers, their siblings, or other people they encountered. Might it be that any and all options for input will do (Atran & Sperber, 1987)? Might it even be that children have ideas of their own about suitable matches between their input needs and possible providers? We know many parents who complain that their children refuse their offers of homework help and turn to others instead. Protests that the teacher's way of doing things is different are common reasons for this in the first author's household.

Such possibilities present no problems for a constructivist theory that incorporates the principle of redundancy. Indeed, because we know that our culture is inundated with samples of mathematical artifacts, things we value, rules of interaction, and so forth, it makes sense to allow different adults to choose specializations when it comes to the job of knowledge transmission. Research is needed on whether it likewise makes sense to let the learners do some choosing.

The risk of failing to provide supporting environments

Ponder the consequences of a case in which parents preferred to give to others the job of knowledge transmission. For example, even though we can assume that parents would have been competent at helping their children with the Racing Balls exhibit, they did not. This was not a neutral decision in this case. First, the materials themselves did not suffice to render transparent to the children the intent of their use. Second, museums and schools often try to start children learning about things they will not encounter in everyday life. Third, because many exhibits are intentionally designed to introduce novel phenomena, it is less likely that the child will have pre-existing knowledge structures to apply. Therefore, novices are by definition more dependent on signposts. When knowledgeable people (parents or otherwise) either cannot or are not always motivated to generate or point these signposts out, learning in such cases is at risk. Had we not succeeded with our computer intervention, very few children would even have used the materials in the Racing Balls exhibit appropriately, let alone learned anything from the exhibit. Indeed, had we not watched what the children first did, we might not even have realized that the exhibit was a failure. It certainly was popular, and there was hardly a time that we did not see children enjoying themselves with it.

Although we were prepared to have the children's use of the exhibit diverge from what we had in mind, we were not prepared for how long it would be before

we reached a meeting of minds. It took two tries to achieve a workable exhibit. No matter how much collective knowledge we had about children and families of this age, the inclinations of preschoolers to count, to be interested in racing, to attend to moving objects, and so forth, we were not inoculated against failure. Most parents did not join the activities of their children, and the children used the items in ways that were not what we had in mind. It is important to emphasize that it took us a great deal of time, work, and experimenting to achieve the successes we did. As pleased as we are that we did this and succeeded, there is no escaping the fact that it was hard, conscious work. Although we always modified our plans in response to the children's reactions, one can hardly classify our efforts as spontaneous and immediate. It was not enough to be knowledgeable, benevolent adults in this situation, and we do not anticipate that it will be in the future. Devising relevant inputs for learning about novel phenomena is hard work—even when one is professionally qualified. It seems unreasonable to assume, then, that children's day-to-day cognitive development could proceed if it really were necessarily dependent on the input of close, personal socializing agents. It must be that there are multiple and redundant sources to which children can turn to find supporting environments for cognitive development.

A Comment on the "Roll" of Language

Without testing further variations in the *Racing Balls* displays, we cannot be sure that we had to have both video illustration and speech. Still, our best guess is that the video alone would not be as effective. One reason is that the combined output of animation plus speech offers redundant exemplars of some of the key features of the exhibit. Furthermore, some messages might require the use of language. Had we used only the video without speech in the *Racing Balls* exhibit, we think many children would have caught onto the idea of using two balls. But our goal was to teach more than this: We wanted children to engage in a mini-experiment, to use data and make predictions, to try to vary the outcomes, and even to get information about the way the exhibit worked. We wanted them to enter the world of science. When put this way, it could be that language had to be part of the communication. There are two reasons to so conjecture. As discussed earlier, objects on their own do not make a scientific experiment. Objects have to be interpreted in scientifically relevant ways for experimentation to happen. Second, mathematics and science have languages of their own, and to interpret objects correctly for use in mathematics and science, one has to use these languages. It is, in part, when one masters the languages within these domains that one has acquired a richer understanding of them (Kitcher, 1982).

These formal languages are very much the invention of mankind, as are many of the things we teach in schools. Given how much effort it took us to

develop one exhibit that did not assume such knowledge, it is unlikely that children's constructivist tendencies alone will suffice for learning math and science. To be sure, knowledgeable individuals can provide such inputs, but so can print, computers, and other media. Even here, then, it is necessary to ask what kinds of social and cultural inputs foster learning. We cannot simply assume that these have to be face-to-face interactions.

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CHAPTER 12

CULTURE AND SOCIALIZATION IN WORK GROUPS

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The goal of this chapter is to analyze the role of socially shared cognitions in work groups. Although these cognitions are important determinants of group effectiveness, they have not received sufficient theoretical or empirical attention. Previous analyses have taken a rather narrow view of the nature and function of cognitions in work groups. Emphasis has been placed on the specific task knowledge that workers need to perform their individual jobs and on the formal mechanisms that professional trainers use in transmitting such knowledge. Much attention has been paid to the broad task and social knowledge that workers need to participate fully in the life of the group and to the informal mechanisms by which group members use in transmitting this knowledge to one another. We believe that an increased emphasis on these topics can produce important insights into work group functioning. Our chapter, therefore, will emphasize worker socialization rather than worker training (cf. Feldman, 1989).

For our purposes, a work group consists of three or more persons who interact regularly to perform a joint task, who share a common frame of reference who have affective ties with one another, and whose behaviors and outcomes are interdependent. This definition is not meant to imply that all work groups are identical. They obviously differ in several important ways, including origin, structure,

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