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An Answer to the Crisis in Education

The basis of the reform of education and society, which is a necessity of our times, must be built upon . . . scientific study.
—MARIA MONTESSORI (1949/1974, p. 12, italics in original)

Two fundamental cornerstones of American schooling today were placed at the turn of the 20th century: the school as a factory and the child as a blank slate. Students of child development know that these ideas are obsolete, but they continue to have a profound impact on how schooling is done. The persistence of these outmoded ideas explains why so few children really flourish in school, and why so many strongly prefer snow days to school days. Yet for most of us, envisioning how to eliminate two such entrenched ideas is difficult.

Early in the 20th century, Dr. Maria Montessori did envision a radically different approach to education, an approach grounded in close and insightful observations of children rather than in adult convenience and misconception. Modern research in psychology suggests the Montessori system is much more suited to how children learn and develop than the traditional system is. In the chapters to come, I describe eight of Dr. Montessori's basic insights, recent psychological research concerning those insights, their incorporation into Montessori classrooms, and why they are often incompatible with traditional schooling. In this chapter I discuss the need for reform, and I trace the roots of the two misguided ideas that form the basis of typical American schooling. I close this chapter with an introductory view of Montessori education.

Dissatisfaction with Schooling

Children and adults alike often proclaim dissatisfaction with traditional schooling. William Blake expressed the child's disenchantment as long ago as 1794:[1]

> But to go to school on a summer morn
> O, it drives all joy away;
> Under a cruel eye outworn,
> The little ones spend the day
> In sighing and dismay.

Albert Einstein hired a scribe to take notes so he could skip classes to escape boredom (Schlip, 1949). Negative feelings toward school remain prevalent today: children applaud the days when they are out of school, and adults frequently comment to children that they are lucky and must be happy when school is canceled. Children of course do not always know what is good for them, but it stands to reason that education would be more successful were it not so frequently disliked. Indeed, a positive emotional climate within a classroom has been shown to be the most powerful predictor of students' motivation to learn (Stipek et al., 1998), and happy moods are associated with more expansive and integrated thinking and learning, and with detecting global patterns (Fiedler, 2001; Fredrickson, 2001; Gasper & Clore, 2002; Isen, 2000). Infants have an intense drive to learn, and school-aged children maintain this drive for learning *outside* of school (Bransford, Brown, & Cocking, 1999). Yet from the early years of schooling, children's motivation to learn *in school* steadily declines (Anderman & Maehr, 1994; Harter, 1981).

Survey research reveals that adults are also discouraged with our schools. *Life* magazine's September 1999 cover story on schools noted that although many of the problematic issues in education were unchanged from 50 years prior, by 1999 a pessimistic attitude had surfaced about the direction in which schools were headed: "In 1950 the answer to [how good are the nation's schools] was: Not very good but getting better. Today, the answer is: Not very good and getting worse." *Life* found that 66% of Americans were "only fairly satisfied" or "not very satisfied" with their community's schools. The 2003 Gallup/Phi Beta Kappa poll showed that 45% of people would give public schools a grade of C to F, and only 11% would give them an A. The 2001 Gallup/Phi Beta Kappa poll revealed that parents' satisfaction with schools diminishes as one moves from small neighborhood elementary schools to larger high schools (this issue was not addressed in the 2003 poll). City schools are often of very poor quality, so families who can afford private schools choose them, and others ask for vouchers to expand their options. Education seems to be in a state of constant crisis in this country.

[1] I am grateful to Mark Lepper for pointing out this poem and the Einstein example that follows.

The Pendulum Response

The American response to this constant crisis has been to swing from conservative and traditional test-oriented programs to progressive and permissive ones, then back to test-oriented programs again, which is where we stand today. A key feature of the United States' Elementary and Secondary Education Act of 2001 ("No Child Left Behind"), the major multimillion dollar school reform act of this era, is a requirement that by 2006 all children in grades three through eight will take standardized reading and mathematics tests annually, and schools will be sanctioned if overall student performance does not improve. The current test-oriented program is driven largely by politicians, who must not be aware of research on the outcomes of such testing. When tests become the focus, teachers teach to and children learn to the tests. As is discussed in chapter 5, research has shown that when people learn with the goal of doing well on a test, their learning is superficial and quickly forgotten.

The opposite swing of the pendulum, to more permissive, child-centered, discovery learning programs is also problematic, because in many instances children in such programs fail to get a good grounding in the basics (Egan, 2002; Loveless, 2001). Progressive school programs have often lacked structure, which is crucial to learning (Mayer, 2004). In the absence of a structured curriculum, wayward teachers can go quite astray, and children's learning suffers. When this is noticed after a period in which innovative programs are tried, the pendulum swings back to traditional test-oriented programs.

Neither extreme addresses the basic problems with schooling. In fact, the record of distally instigated reforms for schools such as No Child Left Behind is not good: state and federal government–led changes in schools have not appeared to make any difference to learning (Wang, Haertel, & Walberg, 1993). Under No Child Left Behind, children appear to do better on the state-sponsored tests they are now being taught to succeed on, but their performance on other standard measures has remained the same or has declined (*New York Times*, December 3, 2003). It is an absolute travesty that politician-instigated school reforms are rarely based on research, but are usually based instead on personal intuitions.

Beyond this, however, is an even deeper problem. When anyone—be it an education professor, a school administrator, or a politician—considers school reform, the changes one tends to consider are rather superficial: this math curriculum, or that one? Longer school day or longer school year? How many children per class—15 or 24? Education discourse in our country does not penetrate the roots of the problem, which are the underlying models on which our education system is founded. To really effect change, reformers must address the fundamental models on which our school system is built, as those models create a host of impediments to children's learning.

Two Poor Models

Traditional schooling is forever in turmoil because of its poor ideological foundation. First, traditional schools are modeled on factories, because the birth of mass public schooling coincided with the age of efficiency. Efficiency is a laudable goal, but it led to the creation of a school system that treats children as if they were all pretty much the same. In some ways they are, but in many ways they are not, and the factory model has a host of consequences that result in suboptimal learning conditions. We might also question its relevance to today's social and economic conditions, in which individual initiative, rather than blind obedience to the bells of a factory, is the key to progress.

The School as Factory

Prior to 1850, the one-room schoolhouse was the dominant form of schooling in America. In such environments, education could be individualized, a wide age span of children occupied a single classroom, and teachers had significant independence in carrying out their didactic duties, responding only to a local board of directors. From the mid-19th century on, a change gradually took place as mass public schooling swept across America (and Europe). This coincided with the age of efficiency, in which a great deal of public discourse was focused on how to streamline business operations for maximum efficiency. Simultaneously, waves of immigrants were arriving on American shores, intensifying the pressure for mass schooling. And by that point the Industrial Revolution had made factories a prominent organizational unit.

Because of this temporal synchrony, modern schools were consciously modeled on factories, with their priority of efficient operation (Bennett & LeCompte, 1990). Like factories, schools were expected to operate under

then-popular "scientific management principles." In the public discourse, which Raymond E. Callahan documented in his classic work *Education and the Cult of Efficiency*, schools were referred to as "plants," children as "raw materials," and teachers as "mid-level managers" (Callahan, 1962). Elwood Cubberly (1916/1929), then dean of Stanford University's School of Education, put it bluntly: schools are "factories in which the raw products (children) are to be shaped and fashioned into products to meet the various demands of life" (p. 512).

One historic moment in this new approach to schools was the 1909 publication by a former school superintendent of Puerto Rico, Leonard Ayers. As secretary of the Russell Sage Foundation's Backward Children Investigation, Ayers ranked 58 school systems in various U.S. cities by their level of efficiency, meaning how many children moved up a grade each year (Ayers, 1909). Ayers was "one of the first educators to picture the school as a factory and to apply the business and industrial values and practices in a systematic way" (Callahan, 1962, pp. 15–16). His analysis was very influential, and low efficiency rankings had school boards across the country up in arms against their administrators. The notion of school as factory, efficiently using taxpayer money to produce educated final products, took firm hold in the wake of this publication.

At around the same time, Taylor management principles were being applied to many aspects of American life, beginning with efficient operation of factories but quickly extending to other businesses, the army and navy, the home, and schools. The aim of Taylor's principles was to increase production via scientific application of conservation practices. Ayers had popularized the goal of efficiency in education; Taylor showed the means. His principles specified that in order to maximize efficiency, worker tasks had to be analyzed, planned, and controlled in detail by the factory manager. In the case of schools, the factory manager was the administrator. The workers, in this case the teachers, were to do as they were told.[2] Taylor management "was given national recognition at the 1913 convention of the Department of Superintendence when the main topic for discussion was 'Improving School Systems by Scientific Management.' There were scores of articles, books, and reports during the next decade on economy in education, efficiency in education, standardization in education, and the like" (Callahan, 1962, p. 23).

John Franklin Bobbitt, a University of Chicago education professor, prescribed steps for the training of teachers in the model of school as factory. School administrators were to tell the teacher-training colleges what

[2] In some discussions of the factory model the children appear to be the workers, and the teachers, the mid-level managers.

sort of teachers they needed, and expect those training programs to deliver. School administrators, he wrote, "have the same right to say to colleges what product shall be sent to them as a transportation system has to say to a steel plant what kind of rails shall be sent to it" (Bobbit, as quoted in Callahan, 1962, p. 88). Once the trained teachers arrived on the job, administrators were to tell teachers exactly how and what to teach. "The worker must be kept supplied with detailed instructions as to the work to be done, the standards to be reached, the methods to be employed, and the appliances to be used" (Bobbit, 1913, as cited in Callahan, 1962, pp. 89–90). Responsibility for teaching was switched from teacher to administrator during this era, which must have profoundly changed the teaching profession and hence schools. Administrators were urged to run the school as a business, teachers were dehumanized (likened to steel rails!), and the child was lost in this early 1900s discourse on how schools should be run.

Several practices that appear to prioritize adult convenience over children's welfare stemmed from these reforms. The practice of having single-age classrooms began early, apparently in 1847 in Quincy, Massachusetts (Nelson, 2002). Whole-class teaching is convenient for teachers and sensible if one has a particular model of children as learners (discussed later), but it also has high costs. Children of the same age can be at different levels within a topic, can have different learning styles requiring different forms of teaching, can learn at different speeds, and can benefit tremendously from interacting with other children who are older and younger than themselves. Whole-class teaching fits the factory model well, but not the child.

Another common practice instituted at this time was the "Gary" or "platoon" practice of shifting children from room to room every 50 minutes at the ring of a bell. This was instigated in the early 1900s (Bennett & LeCompte, 1990) as part of an effort to make schools more efficient in their use of space, but it eventually became integral to teachers' daily lesson plans. Traditional classrooms today still shift topics not when the teacher and children are at a good transition point, but when the bell rings. The teacher is responsible for timing the lesson to match the bells. Every classroom of children is different, but preestablished schedules restrict the possibility of children's needs guiding the lessons and their timing. Another drawback is that children can rarely pursue individual interests and activities, but instead have to follow the program that all the children follow, which is predetermined by the teacher or administrator. When it is math time, everyone must do math, no matter how engrossed some might be in a writing project. The world we are preparing children to work in today is not like this: educated people often determine for themselves when to move from one piece of work to another. Yet the traditional school system still operates like a factory (Bennett & LeCompte, 1990).

The factory model and its consequences emerged from a need by school administrators to justify their use of tax dollars to produce educated citizens for a factory-based economy (Callahan, 1962). The school was yet another factory, producing workers for the factories into which they would graduate. What was best for the child was clearly not in view. It is interesting that schools have become increasingly less efficient as laws have increasingly required schools to educate every child regardless of individual variation. Schools with diverse groups of immigrant children must accommodate several languages, schools that enroll many children with learning disabilities must provide special classes, and so on. The per-pupil cost of education in public schools averaged $7,376 in 1991 (*Wall Street Journal*, December 15, 2003, p. A14). School spending has increased enormously over the past thirty years, with no difference in education outcomes.

Despite these problems, the factory model continues to prevail today. Children in traditional schools are still marched in lockstep through an educational system and even daily schedules and physical structures reflect the factory model. In our current information age, when we deal in more of a commerce of ideas and entrepreneurship than in factory production, use of such a model in education should be particularly suspect. The school system in a sense trains children to be alike, whereas the economy thrives on variations in individual initiative, at least at the levels to which most parents aspire for their children. The factory model makes poor sense both from the standpoint of how children learn and from the standpoint of what society seeks.

The Lockean Child

The second suboptimal model on which our schools are based is the child as empty vessel or blank slate, a view typically associated with the 17th-century philosopher John Locke. The early 1900s instantiation of this view was behaviorism, the view that one could elicit a number of different behavioral profiles in an organism by varying the consequences of its behaviors. The continued prominence of behaviorism in schooling is clear:

> We have inherited an education system designed in the early part of this century. . . . [This system's] espoused curriculum and teaching norms were based on prevailing scientific assumptions concerning the nature of knowledge, the learning process, and differential aptitude or learning. Although they have been profoundly challenged by the past three decades of research in cognitive science and related disciplines, the assumptions of the 1920s are firmly ensconced in the standard operating procedures of today's schools. (Resnick & Hall, 1998, pp. 90–91)

The Lockean or empty-vessel model of the child was adopted in schools of the early 1900s in part because it was embedded in school practices prior to that time. For example, in schoolrooms prior to 1900 rewards for good performance and punishments for poor learning were commonplace. These prior practices paved the way for behaviorism to become the prominent learning model during the period of transition from one-room schools to large public schools. Another important reason the model gained such prominence was the work of one of the great figures in behaviorism, Edward Lee Thorndike.

An eminent professor of psychology at Columbia University's Teachers College for 40 years, Thorndike vastly influenced teacher education. Still prominent today, Teachers College was then, when the field was still new, the foremost teacher-education institution. Its early Ph.D.s became the establishing professors at other new schools of education across the nation. Thorndike was a man of such force, according to his dean, James Earl Russell, that he shaped not only the character of Columbia Teachers College, but also the entire field of teacher education in its infancy (Russell, 1926, as cited in Jonich, 1962). "Coming to the field of educational psychology in its early, formative days, Thorndike was able to dominate its course to an extent hardly possible to one man today" (Jonich, 1962, p. 2). Spreading his influence through writing as well, he published over 500 articles and books, including a series of popular elementary school textbooks (Jonich, 1962).

Thorndike viewed the teacher as the major force in educating the child, and the teacher's task as being to change the child. To do so, he said, the teacher must "give certain information" (Thorndike, 1962, p. 59) and "control human nature" (p. 60). The only means the teacher possessed to do this were speech, gestures, expressions (p. 60), and a behaviorist curriculum based on associations between items learned and rewards administered.

To cement such associations, Thorndike argued that every topic should be broken down into discrete learning items on which students would then be drilled to form mental bonds. Well-formed bonds were to be rewarded with "kind looks, candy, and approval" (Thorndike, 1962, p. 79), and poorly formed ones were to be met with punishment. Repetition was the key to well-formed bonds. Against any notion of discovery learning, Thorndike argued that bonds should be created for the information necessary, and no more.

An illustrative example of how Thorndike thought about necessary information concerns vocabulary. He believed that children should focus only on the most common words in the language, and he therefore published *The Teacher's Word Book*, listing the 10,000 most commonly used words in the English language (Thorndike, 1921a). Children's textbooks were considered useful to the degree to which they used these words, and few other "useless" (to Thorndike) ones (Hilgard, 1987). Evidently the age of efficiency and behaviorism were mutually reinforcing.

The Teacher's Word Book was but one of Thorndike's widely acclaimed books. His many textbooks supplied teachers with information already broken down into discrete learning items, and via these learning programs he wielded tremendous influence. His textbooks were adopted by the state school systems of California and Indiana. The income generated from sales of his textbooks across the United States was said to be five times his teaching salary in 1924 (Jonich, 1968, p. 400, as cited in Hilgard, 1987).

Thorndike's textbooks are classic illustrations of the decontextualized material common in American textbooks today. For example, one Thorndike textbook problem is: "Tom had six cents in his bank and put in three cents more. How many cents were in the bank then?" (Thorndike, 1917, p. 18). The reader knows nothing about Tom or his bank, and so must process disembodied information. In contrast, the problems one regularly encounters outside of school tend to have a meaningful context.

Thorndike believed that children could not transfer learning from one context to another unless elements of the situations were identical, so supplying context was useless. This belief was based on his 1898 dissertation, one of the most frequently cited studies in American psychology (Hilgard, 1987). In his study adults were asked to estimate the area of different polygons (including rectangles), were then given feedback (training) as they estimated the area of rectangles, and, in a final test phase, were asked again to estimate the area of various polygons. Thorndike found that training on rectangles did not lead to improved performance on all of the polygons, but only on the rectangles. From this he inferred a general principle that human learning does not transfer to different situations, and he concluded that one could and should therefore educate children merely by strengthening bonds for the very information they needed to know, stripped of context. Thus, children were instructed in Thorndike's texts as follows: "Learn this: 1 dime = 10 cents. 1 nickel = 5 cents" (1917, p. 59). And so on. Thorndike's view that knowledge can and should be presented in textbooks, as a set of disembodied, unconnected written facts that children have to commit to memory to become educated beings, still dominates.

Psychological research since has quite clearly demonstrated that children do in fact transfer learning from one context to another, and that a more apt view of learning is that the child can construct knowledge, rather than simply form associations (Bransford et al., 1999; Kuhn, 2001; Peterson, Fenneman, Carpenter, & Loef, 1989). We also know today that learning with a meaningful context can be far superior to learning that is unconnected to its use. For example, street children who sell things show mathematical understanding that they cannot even apply to the decontextualized problems in schoolbooks (as discussed in chapter 7). Sometimes people have knowledge that they can use in everyday situations but cannot transfer to the more removed contexts of school. We also know that rewards can have detrimental effects on children's engagement in learning activities, and yet we continue to reward and punish children with grades. Schools today commonly use programs in which elementary school children "read for pizza" or other rewards (including money). Despite advances in our understanding of how children learn, the legacy of behaviorism is still quite clear in the textbooks, curricula, and methods of schooling in place today.

Why Poor Models Stick

Over the years several alternatives to the behaviorist view have been provided by educational theorists such as Dewey, Piaget, Bruner, and Montessori. These theorists are referred to as constructivists, because they view children as constructing knowledge, rather than simply taking it in like an empty vessel. When one takes a constructivist stance, meaningful settings become important for learning, because one uses tools and materials from the environment for that construction. Because constructivism aligns with results from recent research on children's learning, it is taught in schools of education. One might say that constructivism has won out over behaviorism in the halls of academe. However, although constructivism is taught in education courses today, research suggests that teachers have difficulty implementing the constructivist approach in American schools. As a result, the approach has had waves of popularity followed by retreat (Zilversmit, 1993). John Dewey, America's most famous progressive educator, lamented near the end of his life that he had not made any real impact on schooling (Dworkin, 1959). Given that constructivism is a better model for learning, there must be strong reasons for its failure to penetrate schooling.

One reason, proposed by the historian Arthur Zilversmit (1993), is response to social and economic circumstances. He noted that retreats from constructivism have come at times of social and economic upheaval, such as the Great Depression and McCarthyism. At such times experimentation falls away in many domains as people opt for the comfort of familiarity. Traditional schooling, for all its faults, always offers the benefit of familiarity to adults who themselves were educated in traditional ways.

Another reason is that education students rarely really understand constructivism and thus fail to implement it well (Renninger, 1998). When they begin teaching, the superficiality of their understanding becomes apparent, and they take up the traditional methods used by their own elementary and high school teachers. Traditional teaching fits both a teacher's memory and

the culturally dominant view of what school is, and teachers who have less understanding of alternatives will naturally fall back on it.

Another reason, I believe, is that the very structure of schools, from physical arrangements to schedules to the ubiquitous use of textbooks and tests, supports behaviorist techniques and thereby leads teachers to take a fundamentally behaviorist approach. If the teacher has a desk in front of a blackboard at the front of the classroom and students are seated in rows facing the teacher, small group or individual work is unnatural. The physical format is designed for lecturing. Although elementary teachers in particular increasingly allow children to sit in clusters instead of rows, other physical learning structures still gear them toward the model of an empty vessel. Learning in traditional schools comes largely from books, even during years when children in traditional schools are not yet particularly good readers. Because of this, teachers must tell children the information that is in the books in order for children to learn. This can only be reasonably accomplished through whole-class teaching.

The 50-minute hour requires that all information be delivered in a set period of time, rather than allowing for fluid and flexible learning depending on the children's interests and needs. Standardized tests on factual knowledge require that a certain body of information be transmitted by a certain date. Standardized tests also embody a view of knowledge as a fixed set of formulas and facts that can be applied and circled on tests. The materials used in traditional schools are geared toward this inert view of knowledge (D. K. Cohen, Raudenbush, & Ball, 2002). Teachers have to work very hard to use unconventional methods in the face of all the structural support schools provide for the traditional method.

Another important reason we continually retreat from constructivist approaches is that with the exception of Maria Montessori, constructivists, in contrast to Thorndike, have not provided teachers with a broad, detailed curriculum. Dewey had many ideas that have stood the test of time, but he did not leave the legacy of a full curriculum. In the absence of a curriculum, teachers who want to teach from a constructivist model of learning are on their own in figuring out how to implement the ideas. Because not enough teachers have succeeded in doing so well, the approach has repeatedly been branded as inadequate.

Few schools today have truly constructivist programs, and although teachers might leave schools of education versed in constructivist theories, their classrooms are run largely according to traditional schemes. Cook and colleagues demonstrated this in a case study of a star elementary education student as she moved from university coursework to practicum to classroom (Cook, Smagorinsky, Fry, Konopak, & Moore, 2002): at each step, she endorsed a more behaviorist approach to teaching. Penelope Peterson and colleagues demonstrated the endorsement of behaviorist principles on a larger scale with a study of first-grade teachers (Peterson et al., 1989). However, they also noted that with more teaching experience (mean of 15 years), teachers returned to endorsing more constructivist views.

Although constructivists have had the greater influence in the academic world, behaviorists were "more influential on the practices in the traditional schools, which were always more numerous than the innovative ones" (Hilgard, 1987, p. 678). Despite research and teaching experience leading to a constructivist model of the child, elements of educational institutions—textbooks, the basic structure of the classroom, and so on—reinforce the Lockean model so much that it continues to dominate. Beyond the physical artifacts reinforcing the Lockean model are the collective memories of teachers and parents. When considering children and how to treat them, there is a strong tendency to revert to one's own childhood. Finally, behaviorist methods appear to work in the short run. As will be discussed in chapter 5, once children are trained to study for rewards, removing the rewards negatively impacts learning. All these factors work in concert to impede school change.

Implications

The empty-vessel and factory models have many implications for schooling, which are discussed in the chapters to come. To preview, when the child is seen as an empty vessel into which one pours knowledge and then creates bonds, there is no need to involve the child actively in the learning process: empty vessels are passive by nature. Yet people learn best when they are actively engaged. Good teachers try to keep children active by asking lots of questions during lectures, but the physical structure of the classroom is designed for passivity: the child sits and listens to the teacher, who stands at the blackboard and delivers knowledge. There is no need to consider the child's interests in the prevailing model because empty vessels have nothing in them from which interests could stem. When interests do arise, since all vessels have been filled with the same stuff, all vessels should share interests. Empty vessels certainly cannot make choices, and so teachers or school administrators choose what should be learned, down to the micro-details tested on statewide examinations.

The factory model also has certain implications for schooling. Factories at the turn of the century were efficient because all raw materials were treated alike. Factory workers operated on material, and material was passive. The material was moved from one place to another, assembled on a set schedule. Based on the factory model, all children in a class are given the same information simultaneously and are often moved from one place to another at the ring of a bell. It is a significant strike against the factory model that even true factories are changing practices to improve long-term productivity, by allowing teams of workers to develop products from start to finish rather than having the product moved from place to place (Wompack, 1996). Yet schools still operate like the factories of yore.

Innovations are, to be sure, happening in traditional schooling. Some people will read the chapters to come and respond that their own children's schools are incorporating evidence-based changes, making them more like Montessori schools—eliminating grades, combining ages, using a lot of group work, and so on. One could take the view that over the years, traditional schooling has gradually been discovering and incorporating many of the principles that Dr. Montessori discovered in the first half of the 20th century. However, although schooling is changing, those changes are often relatively superficial. A professor of education might develop a new reading or math program that is then adopted with great fanfare by a few school systems, but the curricular change is minute relative to the entire curriculum, and the Lockean model of the child and the factory structure of the school environment still underlie most of the child's school day and year. "Adding new 'techniques' to the classroom does not lead to the developmental of a coherent philosophy. For example, adding the technique of having children work in 'co-operative learning' teams is quite different than a system in which collaboration is inherent in the structure" (Rogoff, Turkanis, & Bartlett, 2001, p. 13). Although small changes are made reflecting newer research on how children learn, particularly in good neighborhood elementary schools, most of the time, in most American schools, traditional structures predominate (Hiebert, 1999; Stigler, Gallimore, & Hiebert, 2000), and observers rate the majority of classes to be low in quality (Weiss, Pasley, Smith, Banilower, & Heck, 2003). Superficial insertions of research-supported methods do not penetrate the underlying models on which are schools are based. Deeper change, implementing more realistic models of the child and the school, is necessary to improve schooling. How can we know what those new models should be?

As in the field of medicine, where there have been increasing calls for using research results to inform patient treatments, education reform must more thoroughly and deeply implement what the evidence indicates will work best. This has been advocated repeatedly over the years, even by Thorndike. Certainly more and more researchers, educators, and policy makers are heeding the call to take an evidence-based stance on education. Yet the changes made thus far in response to these calls have not managed to address to the fundamental problems of the poor models. The time has come for rethinking education, making it evidence based from the ground up, beginning with the child and the conditions under which children thrive. Considered en masse, the evidence from psychological research suggests truly radical change is needed to provide children with a form of schooling that will optimize their social and cognitive development. A better form of schooling will change the Lockean model of the child and the factory structure on which our schools are built into something radically different and much better suited to how children actually learn.

Montessori Education

In the first half of the 20th century, Dr. Maria Montessori, a highly intelligent, scientifically minded woman who herself had been bored in school, decided to address the problem of education with a fresh outlook. In effect, she redesigned education from the ground up.

Historical Overview

How Dr. Montessori went about developing her program is an interesting story (Kramer, 1976; Standing, 1957). She lived for much of her childhood in Rome and had unusual pluck and drive, aiming for a degree first in engineering and later in medicine, both unheard-of courses of study for a young Italian woman at the time. After her medical training she worked in psychiatric clinics, where she became interested in helping mentally retarded children. At the beginning of the 20th century, mentally retarded people were often institutionalized in bare rooms, their food thrown at them. Dr. Montessori saw in their grasping at crumbs of food on the floor as starvation not for food, but for stimulation. She studied the methods of Jean-Marc Itard, who had worked with the Wild Boy of Aveyron, and his student Eduard Seguin seeking methods of providing such stimulation. Seguin had developed a set of sensory stimuli for the education of retarded children, and Dr. Montessori adopted these in her work, creating what in Montessori terminology are called the Sensorial Materials.

In 1901, the mentally retarded children with whom Dr. Montessori had worked passed state educational tests designed for normal children, an event that aroused international attention. Newspaper articles the world over marveled at the amazing Italian physician who had brought "defectives" (as they were then called) to this feat. Dr. Montessori had a different reaction. Rather than marveling at what the mentally retarded children had done, she instead marveled at the fact that normal children were not doing better on such tests, given their obvious advantages. Then, as the famous Swiss psychologist Jean Piaget (1970) described it, "generalizing her discoveries with unparalleled mastery, Mme Montessori . . . immediately applied to normal children what she had learned from backward ones: during its earliest stages the child learns more by action than through thought [, leading her to develop] a general method whose repercussions throughout the entire world have been incalculable" (pp. 147–48). Dr. Montessori turned her studies to the process of normal development in order to discover how human beings could reach their potential more fully than they did in traditional schools.

The process of application was not actually as immediate as Piaget claimed. First, following her success with retarded children, Montessori returned to school herself, this time to study education. She observed children in traditional classrooms to try to decipher why they were not advancing more in that environment. As she developed new ideas, Montessori requested permission to apply them in public elementary schools, but the governing bodies in Rome at the time would not give her access to those children. In retrospect this limitation was probably providential, because the system she eventually developed for older, Elementary school children was based on children who had been in her Primary programs from ages 3 to 6. These children had at the outset a different set of skills and knowledge relative to other 6-year-olds, and the Elementary program could thus be built for children who were already reading and writing, who knew how to follow procedures and to make their own decisions about what to do next, and who understood some basic principles about how to get along as individuals in a large group.

Because she could not initially work in elementary schools, Dr. Montessori took an opportunity that arose to work with younger children. A housing project was undergoing renovation in a poor section of Rome, and children who were old enough to run about unsupervised but were not yet of the age for school were causing problems in the renovated buildings. The project developers decided to intervene. Knowing Dr. Montessori was interested in working with normally developing children, they offered her a space in one of the projects and the care of 50 or 60 children aged 3 to 6. A young woman served as teacher, and Dr. Montessori began her "experiment" in January 1907. She viewed her schools as laboratories in which to study how children learn best (Montessori, 1917/1965, p. 125).

Because legally the classroom could not be called a school, Dr. Montessori was not allowed to order typical school furniture or items, another limitation that ended up being advantageous. She furnished the classroom instead with small furniture she had specially designed for children. This furniture was typical of what one might find in a home, like small tables and armchairs. She put in various materials, gave the young teacher instructions on what to do, and then retreated to her other roles as a professor at the University of Rome, a researcher, a practicing physician, a renowned speaker on women's rights, and a student taking classes in education (Kramer, 1976). But she found time to observe the classroom, and the teacher also reported to her in the evenings about what had transpired. Dr. Montessori is said to have worked late into the nights making new materials for the teacher to try. By testing new approaches and materials and noting children's reactions, over the next 50 years Dr. Montessori developed a radically different system of education.

Dr. Montessori developed materials for education in concert with ideas about it, and the materials were field tested until she believed she had found reasonably optimum ones for teaching a given concept. She also tested materials across ages and frequently found a material appealed to children much younger than those for whom she had designed it. "We watched the younger children go among the older ones, and . . . we saw them become interested in things which we had thought previously too remote from their understanding" (Montessori, 1989, p. 68). Young children, she found, are much more capable than traditional curricula hold them to be, a finding that put her at odds with the educational trends of her time to "dumb down" the curriculum for young children (Egan, 2002; Hall, 1911).

In contrast to other constructivists, Dr. Montessori left the legacy of a broad, field-tested curriculum covering all the major subject areas—math, music, art, grammar, science, history, and so on—for children ages 3 to 12. This system was developed by trial and error over her lifetime, with children in places as diverse as Rome, India, Spain, the Netherlands, and the United States. Dr. Montessori gave many lectures and wrote several books about her system, and she founded the Association Montessori Internationale (AMI) to carry on her work including the training of Montessori teachers. A *Casa dei Bambini* operates today at the original location, at 58 Via dei Marsi near the University of Rome (see Figure 1.1).

A Portrait of a Montessori Classroom

For the next half century, Dr. Montessori adjusted and adapted her educational system to better serve children's needs, and well-functioning Montessori classrooms typically share many features reflecting those adjustments. The importance of several features is emphasized here; later chapters discuss psychology research pertinent to many of these features and more.

A Montessori classroom is usually a large, open-feeling space, with low shelves, different sizes of tables that comfortably seat one to four children, and chairs that are appropriately sized for the children in the classroom (see Figure 1.2). Although not unusual today, making furniture that was appro-

FIGURE 1.1. The *Casa dei Bambini* today at the original location, at 58 Via dei Marsi near the University of Rome. Photograph by the author.

FIGURE 1.2. A Montessori classroom

priately sized for the children who would use it was one of Dr. Montessori's innovations (Elkind, 1976). Traditional Montessori classrooms always have at least three-year age groupings; at smaller schools all six years of Elementary might be combined.

The Montessori classroom is arranged into areas, usually divided by low shelving. Each area has "materials," the Montessori term designating educational objects, for working in a particular subject area (art, music, mathematics, language, science, and so on). This contrasts sharply with traditional education, in which learning is derived largely from texts. Books become more important as tools for learning at the Montessori Elementary level, but even there, hands-on materials abound. Dr. Montessori believed that deep concentration was essential for helping children develop their best selves, and that deep concentration in children comes about through working with their hands, hence materials.

Montessori classrooms also contrast with many traditional ones in having a pristine appearance. Extra materials are kept out of sight in a closet and rotated in and out of the classroom as children seem ready for or no longer in need of them. Every material has its place on the shelves, and children are expected to put each material neatly back in its place after use, ready for another child. Attention to the community and respect for the needs of others are highly valued. Such attention is also reflected in how

teachers arrange the classroom. Materials both within and across subject areas are placed thoughtfully, so the arrangements make logical sense.

Children are not assigned seats but are free to work at whatever tables they choose, moving about in the course of the day. They can also work on the floor atop small rugs. Children can choose to work alone or in self-formed groups, except when the teacher is giving a lesson. With very few exceptions, all lessons are given to individuals (more often in Primary, the 3- to 6-year-old level) or small groups (more often in Elementary, the 6- to 12-year-old level). Lessons are given as the children are ready for them; the teacher might write on the board or announce the day's planned lessons early in the day, so that children will know what to expect. Care is taken so that the effect is not to impose control on the children, but simply to alert them so they can plan their day accordingly.

Montessori education is organized to the core. At the preschool level, this sometimes puts people off. They enter a Montessori classroom, and unlike preschools they normally see, it is very quiet. Children are calmly working alone or in groups. And their work is organized. They are concentrating, carrying out activities in a series of steps that have been shown to them by the teacher or other children. As will be discussed in chapter 9, research suggests that orderly environments are associated with the best child outcomes, but the degree of order can make parents feel uncomfortable.

The materials on the shelves are designed to attract children's interest and to teach concepts via repeated use. Most of the materials are made of wood and are either natural or painted in bright colors selected because those colors were found to attract children. Each material has a primary reason for its being in the classroom; most also have several secondary purposes as well. Rather than giving tests to assess competence, Montessori teachers observe children at work, noting whether children use the materials correctly. Correct use is believed to engender understanding. Teachers repeat lessons when children appear to be using a material improperly and thus will not draw from it the learning it is intended to impart; new lessons are given when children appear to have mastered a material and to be ready for the next material in a sequence.

In keeping with each material's having a primary purpose, there are particular ways to use the materials, which the children are shown in the lessons. Children are not supposed to make music with Metal Insets (a material, shown in Figure 1.3, consisting of standard geometric shapes made of metal, each inside a square metal frame); the Metal Insets serve other purposes, and different materials are provided that are more suited to making music. In addition to the use of each material being highly structured, the overarching Montessori curriculum is also tightly structured. Materials within a curriculum area are presented in a hierarchical sequence, and there

FIGURE 1.3.
The Metal Insets

is a complex web of interrelationships with materials in different areas of the curriculum. As far as I know, no other single educational curriculum comes close to the Montessori curriculum in terms of its levels of depth, breadth, and interrelationship across time and topic.

The materials break important activities into a series of organized steps that children learn separately before bringing them together to do the main activity. These steps often constitute indirect preparation; children are not aware of what the steps can lead to, but the teacher is aware and presents the materials methodically. A good example of how instruction in Montessori proceeds is in the teaching of writing and reading.

Learning in Montessori: Writing and Reading

In Montessori programs, children learn to write before they learn to read, and reading follows spontaneously several months after writing has begun. Several steps lead to the onset of writing in the Montessori Primary classroom. Three-year-olds first engage in activities through which they practice the thumb–index finger (pincer) grip needed for holding a pencil. One exercise that uses this grip involves lifting solid Wooden Cylinders by their small round knobs out of an oblong wooden case (see Figure 1.4). There are four sets of these Wooden Cylinders. The cylinders in one set vary systematically in width while height remains the same, those in another vary in height while the width remains the same, and those in a third change by

FIGURE 1.4. The Wooden Cylinders

both height and width together. The fourth decreases in width and increases in height. The exercise of lifting the cylinders out, mixing them up, and then returning them to their appropriate holes was designed primarily to educate the child's intelligence by engaging the child in an activity requiring that he or she observe, compare, reason, and decide (Montessori, 1914/1965). Focusing on dimension with this exercise also prepares the child for math, and the work enhances the child's powers of observation and concentration. But the addition of the knobs allowed the material to confer two additional benefits geared toward writing: strengthening the finger and thumb muscles and developing the coordination needed for holding a pencil.

The child goes on to develop the wrist action associated with writing by tracing shapes from the Geometry Cabinet, a wooden cabinet containing several trays, each holding six blue two-dimensional wooden shapes set in natural wood frames (see Figure 1.5). One tray holds rectangles of gradually increasing widths, another has different triangles (equilateral, right angle, isosceles, and others), another has a set of irregular geometric shapes such as an ellipsoid and a parallelogram, and so on. Children learn the names of the shapes as they trace along their edges, first with their fingers, developing lightness of touch and the wrist action needed for writing. Later they trace the outlines of leaf shapes in the Botany cabinet but use a delicate orange stick that allows them to get into the corners. This delicate orange

FIGURE 1.5. Triangle Tray from the Geometry Cabinet

wooden stick allows children to practice holding something pencil-like, but without the added concern of making marks that would damage the material. Children learn the names of various shapes of leaves while also (without knowing it) learning the wrist action and pencil grip for writing. Even prior to using the orange wooden stick, "The little hand which touches, feels, and knows how to follow a determined outline is preparing itself, without knowing it, for writing" (Montessori, 1914/1965, p. 96). Clear writing is exact, and such exercises prepare children by engaging them in precise movements.

Later, children learn to hold and use pencils with the 10 Metal Insets (see Figure 1.3), which have the same geometric shapes as the items from the Geometry Cabinet, but are made of metal, with the outer frame painted red and the inset geometric shapes painted blue. Metal is an unusual choice for a Montessori material since metal is cold to the touch; wood is the norm because it feels warmer, and Dr. Montessori perceived this as inviting use. However, metal has the advantage of not being as easily marked by straying pencils, and thus it is the material of the first objects with which children use actual pencils. The child initially sits down with all 10 Metal Insets at once, as Dr. Montessori noticed this inspired children to do all of them, whereas having just one did not (Montessori, 1914/1965, p. 144).

Each of the Geometry, Botany, and Metal Inset items has a small knob like those the children first encountered with the Wooden Cylinders, so

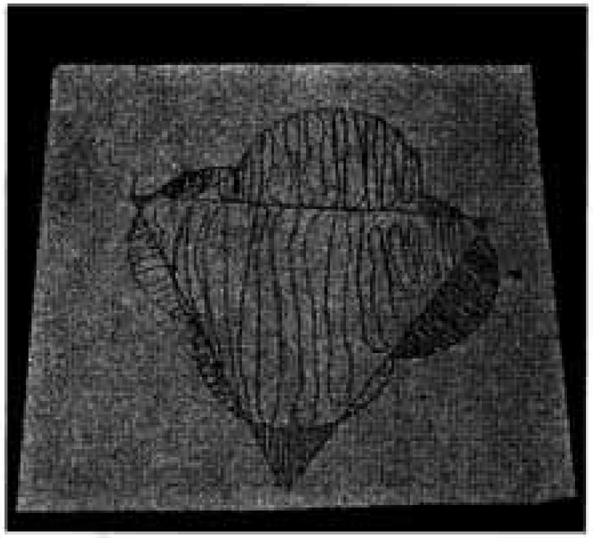

FIGURE 1.6. Metal Inset designs

working with these materials continues to exercise the pincer grip in preparation for holding the pencil. Dr. Montessori intended that exercising such muscles would prevent fatigue when children first begin writing. When 4-year-olds start writing in Montessori, as teachers tell it, they want to do so nonstop. If these exercises really do strengthen the pincer grip, they might support an early enthusiasm for writing. In addition, Montessori teachers pay close attention to whether children are correctly holding the pencil, another step thought to reduce the muscle fatigue that can come from a great deal of writing.

With the Metal Insets, children use 10 colored pencils to trace inside the red frame or along the outside of the inset shape. Later they work on filling in the inset drawings with lines, to work on pencil control (see Figure 1.6). The repeated use of 10 objects (pencils, Metal Inset shapes, and so on) is intentional in Montessori, to reinforce the decimal system. Markers were of course not available when Dr. Montessori developed this system, but many Montessori schools today eschew the use of markers because pencils provide the children with more finely tuned feedback. The intensity with which the child presses a pencil onto paper has immediate and visible consequences: a pencil tip will break if pressed too hard and will not make a mark if not pressed hard enough. In addition, pencils allow shading, and one exercise with the Metal Insets is to shade the inside of a shape from darkest to lightest. Markers do not educate the child as carefully, since no immediate touch-dependent feedback results.

Colored pencils and Metal Insets are later employed to make a won-

FIGURE 1.7. Montessori art: Child at easel

derful variety of creative illustrations in art, an area many people mistakenly think is not part of the Montessori curriculum (e.g., Stodolsky & Karlson, 1972; see the young artist in Figure 1.7). The same misconception is often found regarding music, although Montessori also has a full music curriculum. Not all Montessori teachers implement the full curriculum, sometimes because their training courses are of insufficient duration to cover it. Indeed, Dr. Montessori used two years to teach the Elementary curriculum to teachers, whereas the longest-running Elementary training courses today teach it in a year.

After learning to trace the Metal Insets, children learn to draw a series of connected parallel straight lines inside of the frame, which teaches children to control the hand and pencil in the natural flowing motion of writing. Dr. Montessori saw this flowing motion to be easier for children than stopping and lifting the pencil frequently, so she had children learn cursive writing before learning to print.

During the same period when children are using the Metal Insets in these ways, they are also learning to trace cursive Sandpaper Letters with their fingers, following the same paths of motion one uses to write. As they

FIGURE 1.8. The Sandpaper Letters

trace the letters (shown in Figure 1.8), children learn to say the phonetic sound (not the name) associated with each letter.[3] Later, the Metal Inset and Sandpaper Letter activities come together. Children hold pencil to paper while making the same hand motions they made with the Sandpaper Letters, saying the sounds of the letters, and eventually stringing letters together to write words in cursive. This process is also assisted by the provision of the Movable Alphabet, a wooden box of cardboard letters that children use to make words (shown in Figure 4.4).

There are more materials and also forms of these materials that lead to writing, but this description gives a flavor for the carefully organized curricula a child is given in a Montessori classroom. The outcome of using the materials in this carefully orchestrated sequence, for most children who enroll in Montessori as older 2- or young 3-year-olds, is to be easily writing in cursive during the year when they are 4. Reading emerges spontaneously during the months after writing begins.

Research suggests some long-term advantages for early reading. Eleventh-graders' vocabulary, reading comprehension, and general knowledge were all strongly predicted by their reading ability 10 years earlier, when they

[3] Research supports Montessori's phoneme-based approach to literacy over the much less successful whole-language approach (Rayner, Foorman, Perfetti, Pesetsky, & Seidenberg, 2001).

were in first grade, even when cognitive ability was controlled for (Cunningham & Stanovich, 1997). Preschoolers who were trained in phonemic awareness scored significantly higher on tests of reading comprehension three years later, relative to children in a matched control condition (Byrne & Fielding-Barnsley, 1995). Research has also shown (not surprisingly) that the more one reads, the more one knows, controlling for intelligence and for years of education (Stanovich & Cunningham, 1993). Long-range reading skills are best predicted by a young child's degree of interest in reading (Whitehurst & Lonigan, 1998). Obviously, making reading unpleasant early on by putting children through a difficult and laborious process would not instill enjoyment of reading, and enjoyment of reading is characteristic of those who read a lot. Unlike the laborious process most first-graders go through, learning to read and write in Montessori appears to be a painless process for children. The organized approach Dr. Montessori took to the learning process would seem to be part of why it seems easy. She performed task analyses of different areas, and the Montessori curriculum presents the child with a series of manageable steps in each area aimed at mastering each task. The steps, derived from observations of children, are carefully organized, focus on important skills and information, and culminate in the child's mastery. Moving to a larger scale, these observations led to a method of schooling with a different model of the child and the school than those that prevail in traditional schooling.

Montessori Models of Child and School

Underlying Montessori education is a model of the child as a motivated doer, rather than an empty vessel. The active child is a view often credited to Jean Piaget, who may have been influenced by Dr. Montessori. He was 26 years her junior and early in his career had conducted observations for his book *The Language and Thought of the Child* in a Montessori school. He apparently attended at least one Montessori conference, in Rome in 1934, and was president of the Swiss Montessori Society. Letterhead from the early days of the Association Montessori Internationale lists Piaget as one of its sponsors (Kramer, 1976). Thus it is not surprising that Piaget and Montessori's theories share some crucial ideas, such as the notion of children as active learners (Elkind, 1967). Children in Montessori classrooms work as motivated doers, learning through self-instigated actions on the environment.

The model of the school in Montessori education is also different. Rather than being modeled on the factory, a Montessori school seems more like a miniature and eclectic university research laboratory. Montessori children pursue their own projects, just as do researchers in their laboratories. Like

university researchers, children choose what they want to learn about, based on what interests them. They get lessons across the curriculum, which bears some similarity to researchers going to colloquia or conferences to learn about new areas or techniques. The children talk with and collaborate with colleagues of their choosing. They pass on the fruits of their labors to others by giving talks to the class or other classes in their school and writing up papers. Thus, in Montessori, the child can be seen as a motivated doer in a research university, rather than as an empty vessel in a factory.

This book describes eight insights Dr. Montessori derived through her observations of children that undergird her approach to schooling. These insights are supported today by a good deal of research in psychology and education. Some of the principles can also be implemented in traditional classrooms; in fact, some of the research showing the validity of the principles was conducted in traditional school contexts. However, to develop a system from a principle is very different than to insert a principle into a system that was designed with something else in mind. The eight principles I discuss emerged in the early days of Montessori education, through Dr. Montessori's observations of children's behavior in classrooms that were unusual to begin with. The principles coexist and are deeply engrained in the Montessori system.

Eight Principles of Montessori Education

The eight principles of Montessori Education discussed here are

(1) that movement and cognition are closely entwined, and movement can enhance thinking and learning;
(2) that learning and well-being are improved when people have a sense of control over their lives;
(3) that people learn better when they are interested in what they are learning;
(4) that tying extrinsic rewards to an activity, like money for reading or high grades for tests, negatively impacts motivation to engage in that activity when the reward is withdrawn;
(5) that collaborative arrangements can be very conducive to learning;
(6) that learning situated in meaningful contexts is often deeper and richer than learning in abstract contexts;
(7) that particular forms of adult interaction are associated with more optimal child outcomes; and
(8) that order in the environment is beneficial to children.

Each principle is briefly reviewed in the following sections.

1. *Movement and Cognition*

The first principle is that movement and cognition are closely entwined. This observation makes sense: our brains evolved in a world in which we move and do, not a world in which we sit at desks and consider abstractions. Dr. Montessori noted that thinking seems to be expressed by the hands before it can be put into words, an idea with which Piaget apparently concurred (Ginsburg & Oper, 1979). In small children, she said, thinking and moving are the same process. Piaget restricted this identity claim to the sensorimotor period, but, consistent with recent work in psychology, Dr. Montessori saw at least a close relationship between the two processes continuing past age 2. Based on this insight she developed a method of education in which a great deal of object manipulation occurs. In recent years there has been an explosion of fascinating research on the connection between movement and cognition that speaks to Dr. Montessori's ideas about movement's importance to thought. The findings imply that education should involve movement to enhance learning.

2. *Choice*

A second principle is free choice. Dr. Montessori noted that children seemed to thrive on having choice and control in their environment, and she envisioned development as a process of the child's being increasingly able to be independent in his or her environment. Although good Montessori programs impose definite limits on this freedom, Montessori children are free to make many more decisions than are children in traditional classrooms: what to work on, how long to work on it, with whom to work on it, and so on. Research in psychology suggests that more freedom and choice (within a carefully designed, ordered structure; see below) are linked to better psychological and learning outcomes, as shown in chapter 3.

3. *Interest*

A third principle is that the best learning occurs in contexts of interest. Interest can be more personal, as when an individual has an abiding interest in ladybugs or dogs that seems to come from within, or it can be situational, an interest that would be engendered in many people exposed to such events and activities. Dr. Montessori created situational interest in part by designing materials with which children seemed to want to interact. She also trained Montessori teachers to give lessons in a manner that would inspire children, for example by presenting just enough information to pique curiosity and by using drama in their presentations (particularly with

Elementary-aged children). Montessori education also capitalizes on interests that appear regularly at particular times in development, such as the intense interest children have in learning language in the preschool years. Dr. Montessori noted that young children seem to be driven to acquire word labels for the objects in their environment, so in the Primary classrooms, children are given a great deal of vocabulary. Montessori education also capitalizes on unique individual interest. Children pursue learning that is of personal interest to them—not in a manner that excludes large swaths of curriculum, but in a manner consistent with how we know the very best learning takes place. Rather than memorize facts chosen by a faraway state legislative body, children in Montessori Elementary schools write and present reports on what fascinates them, tying it into the foundational curriculum. The Montessori materials and basic lessons ensure a core of learning across curriculum areas, but each child's imagination is invested in the particular avenues of learning that the child pursues beyond that core.

4. *Extrinsic Rewards Are Avoided*

Dr. Montessori saw extrinsic rewards, such as gold stars and grades, to be disruptive to a child's concentration. Sustained, intense periods of concentration are central to Montessori education. Dr. Montessori recounts children repeating problems (such as getting the Wooden Cylinders into their proper holes) dozens of times in succession, displaying a level of concentration that she herself had previously thought young children were incapable of. At the Primary level, children might concentrate intensely for 30 minutes at a time. By the Elementary level, they might work on the creation of a single chart for much of the day or even several days in succession. The rewards in Montessori education are internal ones. A good deal of research suggests that interest in an already-loved activity, such as learning seems to be for most children, is best sustained when extrinsic rewards are not part of the framework, as discussed in chapter 5.

5. *Learning with and from Peers*

In traditional schooling, the teacher gives the children information, and children rarely learn from each other or directly from materials (except texts, which often tell children rather than helping them discover). Although on the increase, working together is still rare in (traditional) elementary classrooms, where tests, problem sets, and papers are usually if not always done alone. In traditional preschool classrooms, in contrast, children usually play in groups. Montessori education is opposite in these arrangements, and is actually more in line with what developmentalists know about children:

younger children are more apt to play side by side but not necessarily together, whereas elementary-age children are intensely social.

In Montessori Primary classrooms, children may often work alone by choice, but in Elementary classrooms children are rarely seen working alone. They pursue knowledge in self-formed groups, creating products ranging from reports to dioramas, charts to plays, and timelines to musical scores. They leave the classroom together in small self-created groups to interview people outside of the school, or to visit museums or businesses that are relevant to a current project stemming from their own interests. Asked what happens in these small learning groups when one child understands better than the others—a concern that arises out of the individualistic traditional model in which one child might do most of the work—I recently heard a 9-year-old Montessori child respond, "We help each other." Chapter 6 discusses research on what happens when students work together to learn, rather than working as individual units striving for the highest grades.

6. *Learning in Context*

In traditional schooling, children sometimes learn without understanding how their learning applies to anything besides school tests. Dr. Montessori reacted to this by creating a set of materials and a system of learning in which the application and meaning of what one was learning should come across to every child. Rather than learning largely from what teachers and texts say to them, children in Montessori programs learn largely by doing. Because they are doing things, rather than merely hearing and writing, their learning is situated in the context of actions and objects. For example, as described earlier, children go out of the Elementary classroom and into the world to research their interests. A small group of children who have become interested in bridges, for example, may choose to locate a local engineer who will meet with them to explain how bridges are designed. This approach, sometimes referred to as "situated cognition," reflects a movement in education that goes alongside current interests in cultural psychology, apprenticeship, and how people learn through participating in their culture. Evidence concerning the validity of this approach is reviewed in chapter 7.

7. *Teacher Ways and Child Ways*

Dr. Montessori's recommendations on how teachers should interact with children anticipated later research on parenting and teaching. When adults provide clear limits but set children free within those boundaries, and sensitively respond to children's needs while maintaining high expectations, children show high levels of maturity, achievement, empathy, and other desirable characteristics. Traditional schools have sometimes erred by being too authoritarian, conveying a "do it because we said so" attitude that is not associated with positive child outcomes. When progressive schools fail, it may sometimes be because they trade the authoritarian teacher-centered features of many traditional schools for their opposite: permissive, overly child-centered ones. As described in chapter 8, Dr. Montessori prescribed a third style, one consistent with what is called authoritative parenting and known to be associated with the most optimal child outcomes. Her advice to teachers is reminiscent of the adult styles associated with positive child outcomes in other domains as well. This research is reviewed in chapter 8, "Adult Interaction Styles and Child Outcomes."

8. *Order in Environment and Mind*

Montessori classrooms are very organized, both physically (in terms of layout) and conceptually (in terms of how the use of materials progresses). This organization sometimes turns people off: it seems finicky, even obsessive-compulsive. Yet research in psychology suggests that order is very helpful to learning and development, and that Dr. Montessori was right on target in creating very ordered environments in schools. Children do not fare as well in less ordered environments. Chapter 9 reviews research on order and its impact on children. It also speculates on the potential neurological impact of presenting orderly sequences of materials intended to tune the senses.

Further Montessori Insights

Dr. Montessori also forecast other current ideas in developmental psychology not reviewed here. For example, she drew extensively on the idea of sensitive periods, which she credited to Hugo de Vries, the Dutch horticulturist best known for rediscovering Mendelian inheritance. Developmental scientists consider sensitive periods to be times when an organism is particularly primed to develop in certain ways, given certain environmental stimulations. It was many years later that Konrad Lorenz popularized this notion with strong evidence of such periods in goslings, and ethological theory began to be incorporated into theories of human development. Among other sensitive periods, Dr. Montessori identified the first five years as a sensitive period for language in children. She went so far as to claim the innateness of human language (Montessori, 1967a) years before Noam

Chomsky (1959) rocked the world of psycholinguistics with that same claim. She talked repeatedly of how important early experience is to development (Montessori, 1967a), well before research in neuroscience backed that idea (Bransford et al., 1999). She also considered development to continue all the way to age 24, about the age when neuroscientists now believe neurological development is complete (Gogtay et al., 2004). In these and other ways Dr. Montessori was clearly well ahead of her time. A natural question at this point is whether the educational system she developed incorporating such insights has outcomes that are superior to those of traditional schools.

Research on Montessori Outcomes

The majority of published work on Montessori shows positive outcomes; however, like most fieldwork on education outcomes, the findings must be taken with a grain of salt because of methodological shortcomings. Good research on the effectiveness of different school programs is actually very difficult to do (Mervis, 2004). One common shortcoming is lack of random assignment: parents choose to send their children to Montessori programs. Features of parenting tend to swamp features of schools when it comes to education outcomes. Parents who happen to like Montessori programs might be, by and large, excellent parents: they like order, they like children to be able to make choices, and so on. Such parents would incorporate those features into the child's home life, and the additive benefit of having those features in school might be nil. In the absence of random assignment, one can always argue that parenting, not the school program, was the source of difference.

Another common problem in research on Montessori outcomes is that usually very few classrooms are involved—often even just one or two. In such cases, one cannot tease apart individual teacher effects from program effects. Perhaps the one or two Montessori schoolteachers whose classrooms were sampled in one study were superb teachers, and in another study the Montessori teachers were poor ones. Respectively positive and negative findings would result, with an effect of teacher quality misattributed to an effect of program. Teachers' ability to sensitively respond to students' needs is vital for Montessori education, and variation in teacher quality could have a meaningful impact when few classrooms were sampled.

Another issue is the quality of a school's implementation of the Montessori philosophy and materials. There is no litmus test for calling a school a Montessori school. Even if one uses an accredited school, the different Montessori organizations have very different accreditation criteria, with

some adhering more closely to Dr. Montessori's methods than others. Researchers often have not known how to determine whether a program adheres sufficiently to the principles and curriculum to be considered a good example of Montessori, and instead they tend to trust that if a school calls itself Montessori, then it is a good place to test whether Montessori education matters for outcomes. In this book, I describe Montessori education as conveyed in Dr. Montessori's writings and in the training courses of the Association Montessori Internationale. Although most Montessori schools surely support many of these principles, implementations vary widely. (Variation in Montessori schools is discussed in chapter 10.)

There can be additional problems. The numbers of children involved in the studies are often small. If the research is short term, one cannot tell if effects are lasting. Because of these problems and others, conclusions about the impact of Montessori from existing research usually must be very tentative.

There are a few suggestive studies that get around one or more of these problems. Two Great Society–era studies used random assignment into different Head Start Programs and looked at long-term outcomes (Karnes, Shewedel, & Williams, 1983; Miller & Dyer, 1975; Miller & Bizzell, 1983, 1984). In both studies, the implementation of Montessori was mediocre in all of the classrooms involved, the number of teachers involved was small, and by the end of the longitudinal study period many children had been "lost," so the sample sizes were small (although still representative of the original sample). With these limitations in mind, in both studies, with children randomly assigned to less than a year of mediocre-quality Montessori at age 4, some positive outcomes were obtained for Montessori children relative to children in other types of preschool Head Start programs and these advantages lasted as far out as high school, when the studies terminated. For example, in the Karnes (Illinois) study, fewer Montessori children dropped out of school or were retained a grade. In the Miller (Kentucky) study, the Montessori boys (in particular) had higher standardized test scores than the children from the comparison Head Start programs (such as traditional preschool, Bereiter-Engleman, and Darcy). Although the results were reasonably positive across two studies conducted in different states, caution must be exercised, on the one hand, because the sample size was very small, and on the other, because the Montessori implementation was poor.

A recent study in the Milwaukee public schools (Dohrman, 2003) was free of several of these problems: it involved many Montessori teachers, used data from large numbers of children, and used schools that apparently offered reasonably good Montessori quality. Although subject to the state requirements imposed on all public schools (perhaps use of particular tests and workbooks, for example), the schools involved attained "associated" status with AMI, the accrediting organization that Dr. Montessori started to oversee quality in Montessori schools. In addition, the children had an extended Montessori treatment, from ages 3 to 11, as opposed to less than one year in the work already mentioned. On the negative side, the sample was not randomly assigned. Although the public Montessori school children were admitted by lottery, the lottery losers were not tracked and so were unavailable as a comparison group. This self-selection is problematic. In an attempt to redress this, the group of children with whom the Montessori children were compared was a particularly challenging one with which to find difference: fellow students at their current high schools, who were matched for gender, ethnicity, and socioeconomic status (SES). Over half the 201 Montessori students in the study were placed in Milwaukee's top four high schools. Because many factors might operate to bring children into such high schools, this makes up a very high standard of group for comparison. It would be more optimal if the comparison group were matched at the onset of treatment, rather than four or more years post-treatment.

Given the comparison group, the results of this study are remarkable. Children who were in the public Milwaukee Montessori schools from preschool to fifth grade scored significantly higher on standardized tests (ACT and WKCE) in math and science than did matched controls from their same high schools. Further analyses of these data are underway, but on all measures obtained to date the Montessori group's average score is either equal to or more positive than that of the non-Montessori children.

Still, the results have to be interpreted cautiously. The Montessori group in this study is a self-selected sample, and parental influences may be at the root of the outcomes. The right study, using randomly assigned children, a large sample size, many teachers, an excellent Montessori implementation, a long time span, and a variety of outcome measures, is yet to be done. A different approach, taken in this book, is to evaluate evidence for component aspects of Montessori education and their support in research.

Chapter Summary

Traditional schools have not fared well owing to the fact that the models of the child and school on which they are built—the empty vessel in the factory—fit poorly with how humans learn. The solutions Americans have devised to fix the problems in our schools repeatedly fail because they do not change these fundamental models. The educational system should instead draw on scientific study of how children learn. Taking such an approach clearly points to the value of revising these fundamental models.

Dr. Maria Montessori took just such an approach in the early 20th century, and the importance of her insights is reflected in their similarity to educational principles generated by modern psychological research. This book discusses eight of Dr. Montessori's major insights on how people learn and develop more optimally. Other authors might have arrived at a different eight: it is clearly not an exhaustive list of Dr. Montessori's insights. These insights are well supported by modern psychological research and have clear implications for more optimal ways of educating children.

Maria Montessori, Barcelona, 1926. Photograph courtesy of the Archives of the Association Montessori Internationale.

MONTESSORI

THE SCIENCE BEHIND THE GENIUS

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Photographs by An Vu

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The Impact of Movement on Learning and Cognition

> One of the greatest mistakes of our day is to think of movement by itself, as something apart from the higher functions. . . . Mental development must be connected with movement and be dependent on it. It is vital that educational theory and practice should become informed by this idea.
>
> —MARIA MONTESSORI (1967a, pp. 141–42)

Movement and learning are perpetually entwined in Montessori education. Beginning in the home or day care, infants sleep on floor beds instead of cribs, so they can move around an entire room to explore and get objects. In Primary classrooms, children move to wash tables and trace Sandpaper Letters, to put large wooden map pieces in place, and to play scales and then compose music on Musical Bells. Older children carry out verbal commands written on cards, both to confront semantic precision and to experience what a verb is. They place colored symbol cards next to words to designate parts of speech. Countable squares and cubes illustrate mathematical concepts: a child can see, feel, and manually count why 3^3 equals 27. Other mathematics materials work through the child's hand to show how the same formula for area can apply to a regular and an irregular shape. The possible examples are endless: in Montessori classrooms, learning is accomplished through movement.

In contrast, in traditional classrooms most learning is accomplished through listening and reading, reciting and writing. Children spend much of the day seated at desks, taking in lecture information, practicing written exercises, or transitioning between class topics. Except for the symbolic translation involved in writing, their learning is rarely connected to their body movement. For example, children tend to learn what a verb is by reading sentences and finding the verb, not by enacting the verb. They usually

learn how to cube numbers by watching the teacher write a cubing problem on the board, then writing out problems themselves, rather than by making cubes and taking them apart. In traditional schooling, bodily movement is limited and consists largely of reading and writing numbers and letters that abstractly represent the concepts being learned. Today, some teachers in traditional schools incorporate hands-on exercises, which is positive. Yet the exercises are add-ons to an essentially lecture-and-recite-based system and are rarely integrated with other work across subject areas.

The traditional classroom's lack of movement fits the Lockean model of the child, in which learning occurs because the child takes in new information and commits it to memory. Behaviorists believed that the child does this because he or she is rewarded (with stars or grades) for doing so and/or or punished for not doing so. Behaviorists were not concerned with what goes on inside of the child's mind, only with the outcome: proper recitation on an exam. Movement is not important to learning in this view. In fact, it is easier to pour things in empty vessels or to write on blank slates if they are still.

Traditional education's absence of movement is also convenient for a factory model, since all children do a single lesson in concert. If factory-based education relied on hands-on materials through which children move to learn, it would require one set of such materials for each child. This would be prohibitively expensive and impractical in terms of storage. Providing children with several textbooks, into each of which many concepts can be packed and then read about in unison, is far more convenient. The factory and empty-vessel models seem to preclude any sizable portion of school learning occurring through movement.

Dr. Montessori saw the stationary child as problematic, because she believed movement and thought were very closely tied. Movement is therefore integral to the educational program she developed. Recent psychological research and theorizing support Dr. Montessori's idea, with many theorists now claiming that cognition is profitably viewed as embodied (Barsalou, 2002; Lakoff & Johnson, 1999). "Embodied cognition" covers many bases, from the idea that we think in metaphors reflecting how our bodies are constructed and function (Lakoff & Johnson, 1999) to the view that organisms are dynamic systems that develop in adaptation to their environment (Thelen, 2001).

In this chapter I describe research supporting the close interconnection of bodily movement with development, thinking, and learning, and how movement is involved in Montessori education. I begin with basic developmental processes. This may seem an odd place to begin the core of this book, since it concerns development before school age, and even more so because the conclusion I will draw is that Montessori practices encouraging movement in infancy are not necessarily prescribed. Even when self-instigated locomotion is delayed, even when it never occurs (as with paraplegic babies), basic psychological developments still occur in humans. Nonetheless, Dr. Montessori was exactly right in her insight that development and movement are closely entwined. In fact, this insight figures prominently in the most important theory in developmental psychology, that of Jean Piaget, which states that in infancy, intelligence is action (Flavell, 1963).

Movement and Basic Developmental Processes

> Until now, almost all educators have thought of movement and the muscular system as aids to respiration, or to circulation, or as a means for building up physical strength. But in our new conception the view is taken that movement has great importance in mental development itself, provided that the action which occurs is *connected with the mental activity going on*. . . . Watching a child makes it obvious that the development of his mind comes about through his movements. . . . Mind and movement are parts of the same entity.
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> —MARIA MONTESSORI (1967A, p. 142, italics in original)

In this section I discuss research suggesting the importance of movement to very basic developmental processes in infancy, ending with a discussion of Dr. Montessori's ideas about infant movement and about the Practical Life activities in Infant-Toddler and Primary classrooms.

In a classic work published in 1963, Richard Held and Alan Hein tested the impact of self-directed movement on a very basic developmental process: vision. They studied this with kittens because for kittens, as for humans, crucial visual development occurs in the months after birth. Ten pairs of kittens, one a leader and one a follower, were reared in the dark except for three hours each day, when they were placed in a normally lit room. While in this room, the leader kitten had attached to its body a harness and cart that pulled the follower kitten around. This set-up allowed the leader to actively explore the environment, guided by vision, while the follower kitten was passively pulled through the same environment. Although the follower had the same visual experience of moving through the environment, it was not actively engaged in the exploration. After three months, the kittens' vision was tested, and the findings suggested that active movement guided by one's vision was crucial to normal visual development. Whereas the leader kittens responded to such events as looming objects and apparent drop-offs, the follower kittens did not show evidence of perceiving depth. This classic study set the stage for a wealth of research on the impact of movement on the development of human babies. In this chapter I first consider an earlier developmental movement, grasping, before moving to the topic of crawling in human babies.

The Impact of Grasping Objects

Learning to grasp objects has an important impact on an infant's interest in and knowledge about the physical world. First, infants who more actively explore the environment with their hands are also advanced in their ability to perceive object boundaries, noting where one object ends and another begins (Needham, 2000). We know this because infants at 3 and 4 months who were more actively engaged with teething toys during a pretest phase were more likely to show surprise when two objects moved together than when they moved separately, whereas less active object explorers showed the opposite pattern. This suggests that interacting with objects may confer important knowledge of the physical world and how objects should behave. Several researchers have noted that once infants begin to reach for objects, they show increased interest in the world of objects (Fogel, Dedo, & McEwen, 1992), and such interest could be the basis of the later knowledge (see chapter 4).

The finding that babies become more interested in objects once they are able to reach for and grasp them is fascinating in light of recent research with monkeys and adult humans. Specific neurons in monkeys fire in response to objects in reachable space. When the monkeys are given a tool (a rake) that enlarges reachable space, those same neurons fire to objects farther away (Iriki, Tanaka, & Iwamura, 1996). Recent research has shown the same process on a cognitive level for the perception of space in human adults: when adults are given a tool that will reach more distant objects, they judge those objects to be objectively closer than when they lack such a tool (Witt, Proffitt, & Epstein, 2004). We respond to what we can interact with, and once babies begin to reach for objects, they become capable of interacting in an expanded world. Thus, once infants can reach out and grasp objects, they become more attentive to such objects.

The psychologist Amy Needham and her colleagues were interested in whether artificially induced experience picking up objects could induce a heightened interest in objects at a much earlier time in development. If so, that would suggest that it is the ability to get objects, rather than a developmental coincidence in timing, that leads to increased interest in objects. Infants of just 3.5 months of age were given early experiences getting objects via Velcro mittens that enabled them to pick up objects before their manual coordination was sufficient to do so. The results were striking. Infants who had had 10–12 brief play sessions with Velcro mittens later showed far more visual attention to new objects, a much greater propensity to reach for those objects, and even a greater tendency to mouth new objects than did other infants of the same age (Needham, Barrett, & Peterman, 2002). Interest in and knowledge of the physical world were importantly influenced by the ability to get objects.

Other work shows that advances in infants' manual movements are related to advances in their social cognition. Even before they reach 1 year in age, infants appear to attribute goals to others. In some of these experiments, infants watched a human hand repeatedly reach out and grab one of two objects (Woodward, 1998). When the infants seemed to be bored with this scene, as indicated by their looking at it less, the placement of the two objects was switched. The person then either reached for the same object in a new location or a new object in the old location. A tendency to look longer —apparently, to regain interest—when the hand got a new object suggests the beginning of an insight that people have goals. Interestingly, infants who have the artificially induced early grasping experience (again, conferred by Velcro mittens) attribute goals to others earlier (Sommerville, Woodward, & Needham, in press).

This work extends to manual movements besides grasping. Using a similar paradigm, the psychologist Amanda Woodward and her colleagues found that infants who have themselves reached the important developmental milestone of pointing are more likely to understand the function of pointing in others (Woodward & Guajardo, 2002). In addition, infants who are better at carrying out means-ends activities (such as using a cloth to pull a toy toward themselves) earlier are better at interpreting the means-ends actions of others (Sommerville & Woodward, in press). Advances in the use of the hand are clearly related to advances in cognition about both the physical and the social world.

The Impact of Crawling

The onset of crawling has also been linked to a broad array of advances in both the physical and the social domains. These advances include perception of distance, perception of one's own body motion, representation of spatial layout, ability to refer to objects by pointing, and other social and emotional developments (Campos et al., 2000).

One example of the developmental advances that come with self-locomotion in humans is seen in a study of infants' ability to find hidden objects. Infants, some of whom were already moving themselves (crawling or cruising along on two legs while holding something) and others of whom were not yet moving on their own watched from a distance as an experimenter hid a toy under one of two colored cups. Infants were then carried to the hiding place. Even though all infants were of the same age (7 to 8 months), those infants who had been moving on their own the longest were significantly more likely to find the hidden object than were infants with less or no locomotor experience (Bai & Bertenthal, 1992). This suggests that the onset of self-locomotion is related to developmental advances in the representation of self and space.

Self-generated locomotion also is linked to depth perception in human babies, echoing the Held and Hein finding with kittens described earlier. Wariness of heights develops when infants begin to move on their own (Campos et al., 2000). Infants who are not yet crawling are less likely to show a fear response—an increased heart rate—when lowered in a harness over a "visual cliff," a set-up that looks like a steep drop-off, than are infants of the same age who already crawl. This holds true even if a child's experience with self-generated movement is induced artificially, by having them use a walker.[1]

As with grasping, developments accruing with the onset of self-locomotion extend to the social realm as well. A social advance that appears to be related to self-locomotion is following a person's gaze. Following someone's gaze indicates at least rudimentary sensitivity to others' mental lives and thus is an important milestone in social cognition. Some studies of self-locomotion and gaze following occurred in China (Tao & Dong, 1997, described in Campos et al., 2000). At least at the time of this study, urban Chinese infants spent much of their awake time propped in a sitting position on a very soft bed, surrounded by thick pillows to prevent falling. Their parents discouraged crawling to prevent dirty hands, and the infants crawled late relative to suburban Chinese infants who were more often permitted to crawl. When tested in a gaze-following procedure, suburban Chinese infants followed about 75% of gazes, whereas urban ones followed only about 50%. Other studies in both the United States and China have shown that even among crawlers, a child's tendency to follow a gaze is significantly related to the length of time the child has been crawling (Campos et al., 2000). Self-produced locomotion thus appears to open the door to sharing others' mental experiences.

[1] Despite this evidence, parents are advised not to place their children in walkers, which the American Academy of Pediatrics in 2001 recommended be banned from manufacture and sale because of the many accidents associated with their use (www.aap.org/policy/0102.html). Interesting as well is the fact that infants who use walkers reach several motor milestones (crawling, standing alone, and walking alone) later than infants who do not use walkers (Garrett, McElroy, & Staines, 2002).

The Importance of Movement with Goals

Developments in the use of one's body, both in terms of what one can do with one's hand and in terms of being able to move in space, surely also influence one's sense of self as agent. Supporting this is research showing that infants who are given a contingency experience early—being able to kick their legs in their cribs to cause a mobile to move overhead—engage in a lot more kicking than do other infants (Rovee-Collier & Hayne, 2000). In other words, infants who by their movement generate an experience are inspired to continue to engage in that movement, generating more such experiences of how the self can create environmental change.

Research with rats suggests the importance of one's movements having a goal, rather than being mere exercise. Rats were either trained to traverse an elevated obstacle course or given an exercise wheel. Increased density of neural connections was observed in the rats who did the obstacle course, but not in those who simply exercised on a wheel (e.g., Kleim et al., 1998). Purposeful movement appears to be associated with neurological change; mere movement does not.

Purposeful activities are self-reinforcing for infants, and self-generated movement is clearly tied to even very basic processes of mental development. These research findings support Dr. Montessori's contention that, to assist development, children should be encouraged to move their hands and their bodies from an early age.

Movement in the Infant-Toddler and Primary Programs

Movement is deeply implicated in Montessori education. Chapter 1 described a sequence of materials involved in learning how to write, each of which involved carefully prescribed movements: tracing Sandpaper Letters, moving a delicate orange wooden stick around the borders of leaf shapes and geometric shapes, picking up cylinders by their small knobs to strengthen the pincer muscles, tracing the insides of Metal Insets to educate the hand in use of the pencil, arranging objects and moving cards that state each object's name near it, moving cardboard letters to form words, and so on. That description shows the variety of movements children engage in for one learning sequence in the Primary curriculum and contrasts sharply with the traditional method of looking at letters to eventually memorize them for reading (which is traditionally learned prior to writing). Yet the importance of movement in Montessori education is apparent well before the Primary curriculum.

Encouraging Grasping in Montessori

First, Dr. Montessori advised that infants be given objects to explore manually. This seems banal today, but Dr. Montessori's idea that infants should have objects such as mobiles, rattles, and bells to inspire reaching and grasping was apparently revolutionary for her time. Rattles had been provided earlier, but expressly for medical reasons: they included coral, which people thought protected children from illness (Calvert, 1992; McClary, 1997). Surely people must have also seen the entertainment value of such toys, but concern with their use in guiding development was not common at the time. The field of child study, in fact, was in its infancy. More recently, discoveries concerning the impact of "enriched" environments on the brains of laboratory rats has led to Americans filling cribs with all kinds of objects for exploration, but Dr. Montessori advised giving young children only a limited choice of carefully selected objects (see chapter 3).

Her purpose in providing objects was to assist children's manual—and thus their mental—development. "In order to develop his mind a child must have objects in his environment which he can hear and see. Since he must develop himself through his movements, through the work of his hands, he has need of objects with which he can work that provide motivation for his activity" (Montessori, 1966, p. 82). Montessori infant courses present a sequence of objects to be presented to babies as they become more able to move (see P. Lillard & Jessen, 2003). These are intended to encourage babies to move their hands and their whole bodies. For example, as babies become old enough to wave their arms above them, Montessorians hang a graspable ring on an elastic band above babies' heads, close enough so it can be grasped, mouthed, and allowed to pop back in place for an interesting result.

Encouraging Self-Locomotion in Montessori

A still-radical Montessori recommendation for infants is that they sleep on a low mattress on the floor, to give them a larger space in which to move.[2] Parents "child-proof" the entire room. Theoretically, being able to move to interesting places in the environment (such as a low shelf with books or toys) could assist infants' development in learning to move with a purpose. In addition, being able to crawl to objects makes them reachable, and (consistent with the research just described) the environment to which the child

[2] Floor beds are mentioned as a positive innovation by G. Stanley Hall (1911), suggesting the idea was in vogue in Europe at the time.

attends thus probably expands as well. In fact, Dr. Montessori recommended that a baby's toys be placed at a slight distance away at first, in order to encourage the baby to move a short distance to them. As the baby becomes more competent at moving (even prior to crawling) the toys are moved farther away, again to encourage movement. An interesting issue for further research is the Montessori claim that even prior to crawling, babies who sleep on floor beds push themselves about with their legs much more so than do crib babies, and that, once crawling, they crawl more because they are inspired to get objects they can see at a distance. Given the findings just reviewed, such experiences would be expected to have associated developments in understanding the social and physical world.

Montessorians also recommend that babies be given sufficient time on their stomachs to develop upper arm strength, to encourage crawling. Recent research showing a reduced incidence of Sudden Infant Death Syndrome in back sleepers precludes advocating putting babies on their stomachs to sleep, but research has shown that children who sleep on their stomachs reach many gross motor milestones, including crawling, somewhat earlier than do children who sleep on their backs; side sleepers are intermediate between the two (Davis, Moon, Sachs, & Ottolini, 1998), perhaps because they sometimes roll to their stomachs and get some experience pushing up their heads. In another study, at 6 months stomach sleepers were more advanced in their social development and communication relative to back sleepers. In absolute terms, these differences were still apparent at 18 months, but statistically they were no longer significant (Dewey, Fleming, & Golding, 1998). However, one problem dampening the results of this study was that mothers were asked about sleep position only once, at 4 weeks, and it is likely that sleep position changed later. Since parents tend to relax with time, and (at least anecdotally) many babies sleep better on their stomachs, it is likely that a proportion of babies who were sleeping on their stomachs by 3 or 4 months were still classified in the "back sleepers" group. Another study found that only 44% of infants' sleep positions were consistent from 1 week to 6 months (Davis et al., 1998). Montessorians recommend that babies get sufficient time on their stomachs, and research suggests this would impact the precocity of development.

Dr. Montessori recommended that as soon as children are able to walk, use of strollers and other carriers should become minimal (Montessori, 1967a, p. 157) so that babies learn to move on their own. She believed children would develop best if they were in charge of their own movements and free to explore the environment (always with limitations imposed where safety is at issue). She also recommended that young children have a small, stable table and chair at which to eat, from which they can move about themselves, rather than a high chair to which they would have to be

lifted—again to encourage their independence with respect to their own movement. She also believed children's furniture should be lightweight, so children could move it if they desired. Such light furniture would also allow them to learn to control their own movements: if one bumps a light table, the table moves. She believed this would teach children to control their movements better than would bumping into heavier objects, which do not move. In sum, Montessori advocated encouraging movement to assist mental development by virtue of the objects available to infants, the physical space they could access, and the implements with which they are reared.

Potential Impacts of Montessori Practices on Basic Development

All these ideas would be interesting topics of research. Many current cultural practices with infants inhibit self-directed movement. Infant swings, strollers, cribs, and playpens are all about confining infants and making them move passively, like Held and Hein's follower kittens. Do children who live among lighter pieces of furniture learn to control their body movements better? Do any lasting impacts accrue from these different approaches to infant movement?

On the one hand, the research presented here suggests that over the short term, there might be psychological impacts, such as advanced social cognition. However, one principle of development is that very little of a given experience is needed to set a normal developmental trajectory in motion, so whether such arrangements would have any impact beyond the first year is questionable and would require careful study. In addition, babies who lack self-locomotor experience owing to developmental problems otherwise appear to function normally, so there are alternative paths that can be taken to "normal development" in broad strokes. Whether there are developmental differences that only more refined tests would reveal is an empirical question.

An example of the subtlety of differences one might examine is suggested by cross-cultural research on how adults perceive scenes. Although Asians and Americans on the surface appear to think quite similarly, more refined studies have shown that there are fascinating differences in how we perceive scenes. When asked to describe a scene showing fish swimming in a fishbowl, adult Asians are more likely to mention the background (the rocks and plants) than are Americans, who are apt to focus exclusively on the central element or agent, such as the most prominent fish (Nisbett, 2003). This subtle difference, one might speculate, could *in part* result from such factors as opportunities for movement in infancy. Unlike American babies, who, until recently, usually slept on their stomachs, Asian babies have traditionally slept on their backs, so chances are the Americans in these studies were prone sleepers as infants and the Asians were supine sleepers. The prone position leads to earlier crawling and might be one among many cultural practices that subtly influence a focus on agency and the American tendency to locate agents in scenes. Clearly normal development occurs in both cultures, with both sleep positions, and many different cultural practices, including differences in language (see A. Lillard, 1998), could feed into these different orientations toward agency and the world.

Dr. Montessori's ideas about giving infants objects were revolutionary for her time, and her ideas about providing locomotor experience are against the grain today as strollers are increasingly employed to get children through shopping malls and airports. Research clearly supports the view that grasping and self-locomotion have short-term effects on children's understanding of the physical and social world. Over the long haul, normal development (as viewed in broad strokes) still occurs even in the absence of movement, and whether precocious self-movement has subtle but meaningful psychological influences is an open question. Montessori practices in this case are not necessarily prescribed by the research: at least in the ways that have been tested, and in ways that are readily apparent, children with more and less early locomotor experience still reach the same end points in development. For example, children who crawl earlier develop depth perception earlier, but all children with normal vision and experience do develop depth perception at the point in development when it becomes useful (e.g., when they crawl). However, Dr. Montessori's insight that movement and development are closely entwined presaged current psychology research, and knowing earlier that one can move about in the environment and do things may have lasting effects on psychological development that have not yet been noticed or studied.

Beyond Infancy: Montessori's Exercises of Practical Life

Montessori Toddler and Primary programs have exercises designed to inspire movements directed to constructive ends, called the Exercises of Practical Life. These activities take care of such practical life concerns as washing floors, polishing wood, watering plants, and preparing and serving a snack or lunch. Some of the main purposes of including such exercises in the classroom are (1) to educate children's movements to be geared to a purpose; (2) to develop children's ability to concentrate on a task; (3) to help children learn to carry out a series of steps in sequence; and (4) to help children learn to care for the environment. As such, these exercises are foundational to many aspects of Montessori education. With regard to the relationship between movement and cognition, these exercises are particularly important because they employ the body in the service of the mind to fulfill a meaningful goal. Research has not addressed the relationship between development and the longer sequences of actions toward goals that are the Exercises of Practical Life, but the research about the impact of such simpler activities toward goals as grasping objects and crawling to destinations suggests the possibility of a relationship.

Dr. Montessori observed that children are motivated to care for the environment and are capable of doing so if provided with attractive sets of materials geared to that end. She also believed young children to be very attracted to precision in the early years, such that they like to know exactly what sequence of steps to carry out in an exercise, or exactly how to place the soap in a soap dish, for example. She considered early childhood to be a sensitive period for attention to precision, a possibility that would be interesting to explore in research. The Exercises of Practical Life are intended to appeal to such motivations in children.

As one example of a Practical Life exercise, Montessori Toddler and Primary classrooms are normally equipped with a set of materials for Table Washing.[3] This set includes a large basin to fill with water, a plastic mat to go under the table, soap, a scrub brush, a sponge, and a towel for drying. The items are all of a size and weight appropriate to a small child, and are usually of the same color, so that they obviously go together. Like other materials in Montessori classrooms, they are designed to appeal to children, in order to inspire use. The teacher demonstrates for the child a precise sequence of actions that are carried out in Table Washing: carry the items to the table, lay out the plastic mat just so, go fill the bucket to this line, and so on. The child has probably also observed other children carrying out the sequence of actions, enabling him or her to learn by observation (discussed in chapter 6). Table Washing is described in more detail in chapter 9.

What is important about these movements, from a Montessori perspective, is not so much that the table becomes clean, but that the child is engaged in a purposeful activity, employing the hands in the service of the mind. The motions to be carried out are executed in a particular sequence and manner that suit the purpose. This overarching goal of executing a series of actions to fulfill a goal began with the simple operations of reaching and crawling to objects. In terms of Montessori education, it culminates in the schoolwork to come. Practical Life activities educate the child to carry out organized sequences of activity, employing the body in the service of the mind.

[3] Table Washing is capitalized because it is a Montessori exercise, taught in Primary Teacher Training courses.

A somewhat different Practical Life activity for children at the Toddler and Primary levels is Dressing Frames, square wooden frames with a cloth "shutter" on each side and a series of ties, snaps, or buttons or a zipper down the center (see Figure 2.1). These frames assist children in developing the skills needed for fastening their own clothes. This activity is somewhat different from most Montessori Practical Life exercises in that using the Dressing Frames does not accomplish a practical purpose directly: their purpose is indirect. It is interesting to consider why Dr. Montessori developed special frames for learning these particular skills, rather than having children learn on their own clothing, which is the ultimate goal. Practical Life activities normally have a practical end, filling a real need in the classroom. Tables really do get dirty and need to be washed; carrots need to be cut up for snacks; plants need to be watered; shoes are more aesthetically pleasing when polished; and so on. Movement serves real and apparent goals in a Montessori classroom. As is discussed in chapter 7, finding meaning in one's activities is important at all ages, and educators should be concerned that no activity be "busy work." The Dressing Frames are an exception to the Montessori norm of "real" goals, because unlike buttoning one's own shirt, buttoning a Dressing Frame serves no direct practical purpose. Instead of *directly* serving an important goal, the Dressing Frames indirectly assist in that goal by teaching children to use clothing fasteners. The Montessori rationale for this is that working on one's own clothing can be frustrating to an extent that can hamper learning. Dressing Frames provide an alternative, less frustrating, way to learn those skills than using one's own clothing.

The fact that Practical Life activities serve a practical purpose is theoretically important because Dr. Montessori believed that for action to be useful to mental development, "the action that occurs must be connected with the mental activity going on" (Montessori, 1967a, p. 142). Only real goals truly engage the mind in the movement. In addition to providing meaning for actions, Practical Life activities lead children to practice concentration, a hallmark of Montessori education. Through concentration, Dr. Montessori believed children develop an inner calm that they bring to their other activities in the classroom. Dr. Montessori called the peace that she saw to be achieved through concentration "normalization," because she observed that most of children's troublesome behaviors disappeared when they experienced concentration on meaningful activities. Young children's concentration often occurs in the context of their motor activities, for example, in learning to walk, or feeding oneself with a spoon. Concentration is discussed further in chapter 3.

The foundations of Practical Life activities in the Primary years are considered vital to the ability to function well in Elementary classrooms; children who lack the Primary Montessori experience are said to often have trouble settling in and concentrating on Montessori work. They also often lack other skills and knowledge learned in Primary, including such specifically academic skills as reading, writing, and math, foundational vocabulary, and more general skills such as self-motivation, self-direction, and self-discipline. These building blocks for work in Montessori Elementary are expected to be established during the Primary years.

FIGURE 2.1. The Tying Frame

Research on Movement and Cognition

When one moves with a purpose, there is a sense in which one's body is aligned with one's thought. Thought guides action. Thought and body movement can be aligned in other ways as well, as when one moves through represented space or nods one's head while thinking positive thoughts. Research concerning these kinds of alignments is discussed next, followed by presentation of two sequences of Montessori materials to illustrate how Montessori education capitalizes on such connections. The first body of research concerns the representation of space and objects.

Representation of Space and Objects

Studies have shown that when people move themselves through space, both real and imagined, they are better able to represent that space than when they are passively moved though it or do not move at all. In one study, 10-month-olds watched as an experimenter hid a toy under one of two cloths. On four such trials, the infants were then allowed to crawl to where they could remove the cloth and get the toy, and on four other trials they were carried to that place (at crawling speed) by their mothers (Benson & Uzgiris, 1985). On the crawling trials, the majority of the infants found the toy at their first try (by removing the right cloth) on most of their trials. In contrast, only 1 of the 26 infants had this level of success when they were carried to the hiding location. The act of moving themselves in space, rather than being carried, apparently allowed the infants—all of whom were developmentally able to crawl—to better keep track of the spatial layout of the environment.

In another study, school-aged children more accurately imagined a familiar spatial arrangement after walking through the imagined space. To test how well the space was represented, children, who were blindfolded in their bedrooms at the time of testing, were asked to imagine they were in their school classroom, and were then asked to point to various locations in the classroom from the vantage point of the teacher's desk. This exercise was sometimes preceded by walking from their own imagined desk to the teacher's desk. When children had walked across the imagined room to the teacher's desk first, they more rapidly and accurately pointed out locations of objects from the teachers' perspective than they did when they remained at their own imagined desk (Rieser, Garing, & Young, 1994). Walking across one's room, engaging one's body with one's imagination (even while blindfolded), stimulated a more accurate and accessible representation of the imagined school classroom.

This finding naturally extends to walking through the actual space one is representing. In another illustration of movement assisting spatial representation, children learning to read maps did so better when they walked across the territory to be mapped (a new campus) than when they sat in a classroom and merely imagined that territory (Griffin, 1995). This experiment is also particularly relevant to chapter 7, which deals with the importance of meaningful contexts for learning. These three experiments show

that infants and children represent space better when moving themselves through the represented space than when remaining still or being moved passively.

In addition to better imagining where objects are in space, people also better imagine how objects and substances move when they carry out actions that simulate those movements. One study asked people to judge the angle at which a wide and a thin glass, each containing imagined water at the same level, would pour. People were often wrong when they simply thought about the problem: they judged that water would pour out of both glasses at the same angle. However, when they were allowed to tilt glasses of imaginary water, even with their eyes closed, they correctly tilted the narrow glass farther than the wide one (Schwartz & Black, 1999). Thus, when cognition aligned with movement, more accurate representation resulted.

Another study showing the positive impact of movement on cognition addressed the incorrect intuition that when a single object moves, all parts of the object move at the same speed (Levin, Siegler, & Druyan, 1990). Sixth-graders were given one of two treatments aimed at correcting this intuition. One was visual training: children watched as a carousel-like device carried two teddy bears around in a circle. The teddy bears were placed on a single rod, one closer to the center and the other further out on the rod as it rotated around the center of the carousel. The second condition involved the children taking the place of the teddy bears, walking themselves in either the outer or the inner position on the rods of the carousel. After having either the visual or the kinesthetic experience, children judged whether two dogs on a similar device were moving at the same speed. During pre-test, all of the children had incorrectly responded that they were moving at the same speed. After training, the children who moved around the carousel themselves responded correctly on 79% of trials that the outside dog must be moving faster. In contrast, those in the visual training condition were only 46% correct. Bodily movement that was consistent with what was being learned led to better learning than merely observing.

A somewhat different example of the impact of movement on cognition comes from studies of abacus experts (Stigler, 1984). Children who are more expert at using the abacus are more proficient at solving math problems, even when they are not using the abacus. This proficiency apparently stems from the fact that abacus experts imagine the movements they would make were the abacus present. Rendering the symbolic concrete via routine use of the abacus enabled improved calculation even in the absence of the actual movement of the abacus beads. Through Montessori materials as well, the symbolic is rendered concrete.

In sum, several studies show that representations of space and objects are improved when movement is involved. The entwining of movement and cognition is also shown in tasks concerning evaluation and categorization of verbal material.

Movement and Judgment

Many studies also show that when cognitive processing of verbal material and actions are aligned, the processes or actions are faster or more accurate than when they are not so aligned. For example, when asked to shake or nod one's head while listening to messages that are either agreeable or disagreeable, people move their heads faster when the direction of nodding corresponds to the valence of the message (Wells & Petty, 1980). Thus, movement that aligns with what one is thinking is faster than movement that contradicts what one is thinking, even when the relationship between the movement and the thought is fairly abstract, as in nodding and finding something agreeable.

When the central verb of sentences is consistent with their own action, people make quicker judgments as to whether sentences make sense (Glenberg & Kaschak, 2002). Specifically, people are quicker to judge (by pressing a button) the sense of sentences such as "He threw the ball to me" when, to register that judgment, they have to move their hand toward themselves (to press a button that is closer to them than their hand's resting position), consistent with "threw to me." They are slower to judge "He threw the ball away from me" when the button they have to press is closer to them. When the hand and button positions are reversed, the pattern of results reverses, showing that the results stem from the relationship between direction of movement and the concept embodied in the central verb, not some other feature of the experiment. People also categorize objects faster when they simultaneously perform the prototypical action for those objects, for example, making a turning motion while judging a faucet (Simmons & Barsalou, 2002).

Another kind of movement is gesture, which occurs frequently when people engage in conversation. Some have suggested that people might gesture to assist their own cognitive processing of abstract ideas in conversation. A naturalistic study by the anthropologist Elinor Ochs and her colleagues showed that people tend to gesture more when the thoughts they need to convey are more complex. High-energy physicists gestured in ways that simulated what they were thinking, particularly when struggling to understand a new hypothesis (Ochs, Gonzales, & Jacoby, 1996). The physicists seemed to have been capitalizing on the possibility that gesturing can assist cognition (McNeill, 1992). Whereas some believe that gestures can assist the thinking of listeners as well as speakers and that gestures serve a communicative function, others believe that gestures serve to assist lexical retrieval: meaning is often reflected in one's gestures right before the words

that denote that meaning are uttered (Krauss & Hadar, 1999). Both of these theories agree that gesture facilitates thought. Later in the chapter, I will return to the issue of gestures and symbolic developments such as language.

Memory

Many studies have shown that memory improves when one's movements align with what is to be remembered. For example, when students enact the content of action-describing sentences at encoding, they remember those sentences better than when they learn the sentences without enacting them (R. L. Cohen, 1989; Engelkamp, Zimmer, Mohr, & Sellen, 1994). One might be concerned that this is only because when one has to move while memorizing something, one has to put more effort into the memorizing, thus one processes the stimuli more deeply. Other work, however, suggests it is not due to deeper processing. Discussion and writing also involve deep processing, and yet student actors recalled a play character's monologue better when they actively improvised what the character was like than when they wrote about or discussed the character (Scott, Harris, & Rothe, 2001).

In another illustration of the impact of movement on memory, actors have been shown to better recall, five months after the final performance of a play, the dialogue they issued while moving on the stage than the dialogue they issued while standing in one place (Noice, Noice, & Kennedy, 2000). Stage movements tend to reflect in some manner the content of what is being uttered, again suggesting that when movement is in concert with thinking, memory is improved.

Even facial movements are associated with improved memory. People remember humorous information better when they smile (accomplished by making them hold a pencil between their teeth) and anger-provoking information better when they are frowning (the pencil is between their lips) (Laird, Wagener, Halal, & Szegda, 1982). These findings appear to stem from the fact that making facial expressions affects one's mood, which then affects memory, rather the expression affecting memory directly, because people who reported no mood alteration in this paradigm did not show the memory effect. But when facial movement corresponds with the valence of what one is thinking about, one remembers it better, illustrating the close connection between the body and the mind.

Mimicking others' faces also appears to lead to improved recall of those faces. When asked to memorize high school yearbook photographs, people remembered the faces better to the degree that they mimicked those others' facial expressions while viewing them. Interfering with that imitation interfered with the ability to memorize: when participants were asked to chew gum while viewing the faces, thereby eliminating their ability to mimic the expression during encoding, memory performance dropped significantly (Zajonc, Pietromonaco, & Bargh, 1982). Chewing gum did not interfere with other cognitive tasks, so the face-memorizing result was probably not due to mental diversion imposed by gum chewing.

Social Cognitive Processing

Another illustration of the impact of movement on cognition concerning faces and emotion is that to the degree that people mimic a facial expression while judging the content of that expression (smile, frown, and so on), they discriminate the expression more quickly (Wallbott, 1991). Our facial movement even appears to affect our relationships. When we are engaged in conversation with others, we move our faces to mimic theirs (Bavelas, Black, Lemery, & Mullett, 1987; Bavelas, Black, Chovil, Lemery, & Mullett, 1988). The fact that married couples really do come to look more alike over time (which they do; Zajonc, Alderman, Murphy, & Niedenthal, 1987) may be a consequence of this, presumably because habitually mimicking facial expressions leads to the same wrinkle lines (Bargh, 2001).

Research Summary

In sum, there is abundant research showing that movement and cognition are closely intertwined. People represent spaces and objects more accurately, make judgments faster and more accurately, remember information better, and show superior social cognition when their movements are aligned with what they are thinking about or learning. Traditional classrooms are not set up to capitalize on the relationship between movement and cognition. In contrast, Montessori has movement at its core.

Movement in Montessori Primary and Elementary Classrooms

> The study of a child's psychological development must be bound up with the study of his hand's activities. . . . Those children who have been able to work with their hands make headway in their development.
> —MARIA MONTESSORI (1967A, p. 152)

In this section, I show how specific Montessori materials capitalize on movement. First I present some Sensorial Materials, followed by an early sequence of mathematics materials.

Sensorial Materials in the Montessori Primary Classroom

The Sensorial Materials are sets of objects designed to educate the senses. In addition, and perhaps even more important, they also appear to assist the child's concentration, ability to make judgments, move with purpose, and so on. Traditional schooling does not usually have a curriculum to educate the senses, but in Montessori this education is foundational. Primary children shake and listen to the various sounds of the Sound Cylinders, wooden cylinders filled with objects that make different noises when shaken. There are two of each Sound Cylinder, and the child's task is to listen carefully and pair them up. In another Sensorial exercise, children remove Color Tablets from boxes and line them up from darkest to lightest, or match Color Tablets by color first, and later (as color perception becomes more finely tuned) by increasing more similar hues. In another exercise, the Rough and Smooth Boards, children feel different degrees of roughness and smoothness on sandpaper tablets, and pair them or arrange them from smoothest to roughest.

Sensorial Materials are discussed further in chapter 9, on order, because the methodical approach Montessori takes to educating the senses has interesting implications for the organization of the developing brain. The important point for this chapter is that the senses are educated not in the context of passively perceiving, but in the context of making perceptual judgments while acting on the environment. In contrast to traditional education, in which the body is merely a house for the mind, which takes in information, in Montessori education the body is an active entity that moves in the service of the mind. In using the Sensorial Materials, the child has to perceive, make judgments, reason, and decide by his or her actions on materials.

Other Sensorial Materials form the basis for mathematics, by educating the child to attend (via movement) to dimension. There are three materials, introduced after the Wooden Cylinders described in chapter 1, to teach three basic concepts: size (the Pink Tower), thickness (the Brown Stair), and length (the Red Rods). These materials are described in some detail to give a flavor of how Montessori materials have been integrally designed to gradually introduce children to increasingly complex concepts. These concepts are conveyed to children not so much through the eyes and ears (the teacher's verbal introduction is minimal), but through the child's hands with repeated use of the material. Cognition is born from manual movement.

The Pink Tower (shown in Figure 2.2) is a series of 10 graduated cubes, the dimensions of which increase by one unit (one cm) on all sides as one moves from the smallest cube to the largest. The cubes are all the same color, which Dr. Montessori claimed helped keep the child's focus on the dimension of interest, the gradually increasing size. Research shows that Dr. Montessori was correct about this. The "pop-out" effect occurs when just one feature of an object is different from other objects it is among. In such cases, people are much faster to pick out that object, relative to when several features vary among the background objects in a display (Treisman & Gelade, 1980). In contrast, many toys designed for young children vary several dimensions simultaneously (like differently colored stacking cups). Whether this delays children's ability to stack the cups, relative to when they are the same color, is an empirical question. The research with adults suggests that it would.

The smallest Pink Tower cube is 1 cm long on each side, the second is 2 cm, and so on, up to the largest, which is 10 cm per side. The decimal system is thus inherent in this material, which the 3-year-old uses by building a tower of the cubes, placing the largest one on the bottom, the next largest one next, and so on, up to the smallest.

The Pink Tower is normally found in its stacked tower form on the floor in the Sensorial area of a Primary Classroom. To use the Pink Tower, a child takes a small (2' x 3') rug rolled up in a rug container and finds an open area on the floor on which to roll out the rug. She then goes and gets the pieces of the Pink Tower and carries them to her rug. Having to learn to walk through the maze of tables, shelves, and other children's rugs is considered to be important for educating children in control of the body: if you bump into something, it has consequences. The act of carrying the cubes from their usual place to the rug is also considered important, because it provides an opportunity for the child to feel the difference in weight and size in the cubes, something she will notice again when she creates the tower. When the child has placed all the pieces in a random arrangement on the rug, she finds the largest one and begins the tower, placing each successively smaller cube on top of the previous one.

An important aspect of this and many Montessori materials is that they are self-correcting. If the child goes wrong, and misses one of the cubes in the series, she will later be faced with a larger cube needing to go on top of a smaller one. In this way, Montessori materials incorporate what is called the Control of Error, a topic discussed more in chapter 5.

Using the Pink Tower material is intended to bring many concepts to the child's mind via the hand, such as the concept of natural numbers from 1 to 10, the decimal system, and the notion of cubing. Eight cubes the size of the first would be needed to make the second, and so on. It might appear to be odd that a complicated notion like cubing is indirectly introduced at such an early stage, yet Dr. Montessori believed a three-dimensional dif-

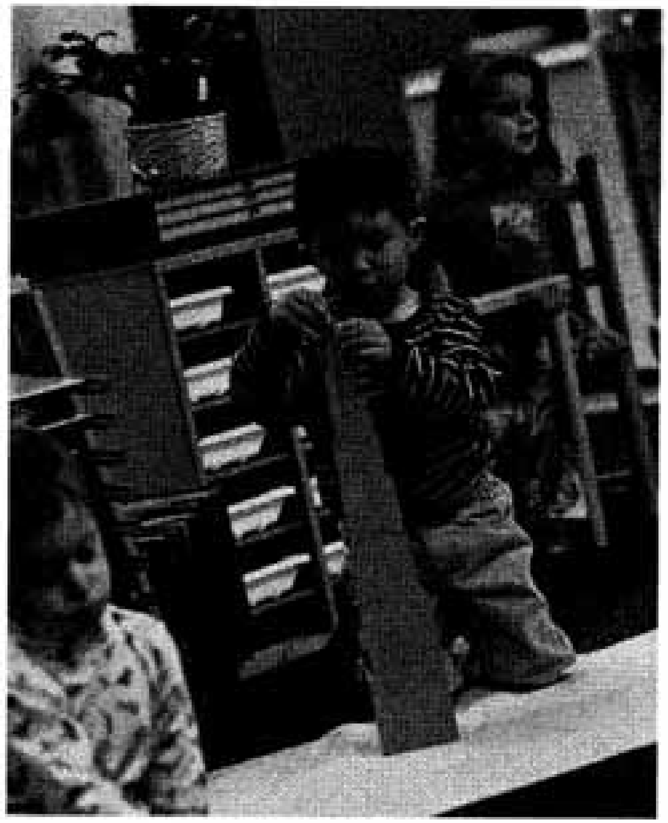

FIGURE 2.2. The Pink Tower

ference is easier for children to perceive than a one- or two-dimensional difference—an interesting question for research.

Working with objects such as the Pink Tower also is intended to train the child's powers of observation, judgment, and decision making: the child must carefully observe features of objects, discriminate differences, and decide which cube to place upon the tower next. Dr. Montessori maintained that by handling these cubes and creating the tower, the child is both coming into contact with basic mathematical concepts and developing important life skills. Whether such work actually does assist the child in these ways remains a topic for empirical investigation. Clearly the intent is that the child's developing cognition is embodied: the child moves in the service of thought, perceiving and then acting on differences in size.

The Pink Tower, like all of the Montessori materials, is used in many more ways, in a series of lessons called extensions. For example, a child will place a second rug across the classroom from the first and will build the Pink Tower on the second rug from a collection of blocks randomly arranged on the first one. This requires that the child keep in mind what he or she needs as he or she traverses the room, so the extension challenges skills of attention and concentration. Another extension has the teacher, or another child, bring some of the cubes to the second rug and ask the child to "Get me the one that is just larger than this one" or "Get me the one that is just smaller." The child has to traverse the obstacle course of rugs and tables in the classroom, all the while bearing in mind the size of the cube that is needed. The Montessori materials have a wealth of extension lessons, leading children to engage with the materials in new ways over many repetitions to further understanding.

The next Sensorial Material to be introduced in the curriculum is the Brown Stair, shown in Figure 2.3: 10 solid oblong wooden blocks ("prisms") of the same length, but of gradually increasing height and width, that can be arranged like a staircase. The height and width of the smallest Brown

FIGURE 2.3. The Brown Stair

FIGURE 2.4. The Red Rods

Stair prism are one-tenth the height and width of the largest one; the ones in between are successively one centimeter different along both dimensions. The children's task is to arrange the prisms from smallest to largest, creating a stair. The mathematical concept of squares is inherent in the materials, as it would take four of the first prism to make the second, nine of the first to make the third, and so on. In building the stair, the child is introduced to the rudiments of such concepts and is given a reason to attend to relative height and width (to arrange them in sequence). Again, there are many extensions on the use of this material; this basic introduction gives a flavor of how dimensional concepts are introduced via the child's actions on objects.

The next material is the Red Rods, shown in Figure 2.4. These rods are all of the same thickness, 2.5 cm on each side. This size was intentionally chosen to be thick enough to support the length of the rods, yet be easily grasped by a small child's hand. The rods vary only in length. The shortest one is 10 cm long, and each successive one is 10 cm longer than the previous one, so the longest rod is 100 cm. One Montessori teacher observed to me that some children do not appear even to see the difference in these lengths at first, but must learn to perceive the difference. The teacher assists the child's learning by showing the child how widely one has to stretch one's arms to hold the longest one versus a shorter one, how the rods differ in weight, and so on. With the help of their bodies, children learn to perceive the differences in the Red Rods and to line them up from shortest to longest. In addition to helping children perceive dimension (which leads into math, as described below), these materials assist children in learning to reason and decide, to concentrate on an activity, to work toward a goal, and so on.

Early Math Materials

The Sensorial Materials in Montessori are designed to introduce mathematical concepts. The transition from Sensorial to Math Materials is a simple step: a new set of rods is introduced, just like the Red Rods, except on the Number Rods each 10 cm unit is painted alternately red and blue. The child carries these rods to his or her rug and arranges them from shortest to longest. The teacher shows the child how to count the units on each rod, arriving at the cardinal number with which it is identified, and to name the rods, "One," "Two," "Three," and so on, while touching each rod. The teacher begins with the shortest few rods, gradually adding more as the child appears to be ready for them. The child touches each unit as she counts, so the hand is bringing the information to the mind. The child also learns to play a game with the rods: one person says, "Give me One, give me Two," and so on, at which the other person hands over the appropriate rod. Later the other party (a teacher or perhaps another child) will say, "What is this?" while holding up each rod, and they will count the parts together, touching each unit with their hands as they name it. The sequence of (1) the teacher showing the child, then (2) asking the child for a particular item, then (3) asking the child to name a particular item is called the "Three Period Lesson." Discussed in chapter 5 as a means of evaluation, the Three Period Lesson is essentially first teaching the child a new concept, then asking the child to recognize the concept, and then finally asking the child to recall the concept.

The Sensorial Materials and the Number Rods introduce abstract concepts via concrete objects. The next step in this sequence of materials is to give children abstract symbols standing for numbers, enabling the possi-

FIGURE 2.5. The Spindle Box

bility of eventually working with larger numbers. To take the child from a concrete understanding of number, based on the length of the rods, into this abstract realm, the teacher shows the child how to place Sandpaper Number cards beside each rod. These are similar to the Sandpaper Letters shown in Figure 1.8.

Montessori introduces numbers not as individual units summed, but as wholes: the length of a rod. This carries over to learning to add numbers. The concept of adding 1 and 3, for example, is introduced by placing the 1 rod at the end of the 3 rod, placing the 4 rod adjacent to that sum, and seeing that the combination of the 1 and 3 rods is equivalent to the 4 rod. Dr. Montessori believed that to learn in individual units, for example by counting out single chips as might be done in traditional schools, the child learns 1 + 1 + 1 + 1, but not 3 + 1 (Montessori, 1914/1965). The question of whether children learn to sum numbers more easily from materials such as the Number Rods rather than individual items is ripe for empirical research.

Individual units are introduced next, with a material called the Spindle Box. Shown in Figure 2.5, the Spindle Box is a wooden box with ten equal compartments labeled 0 to 9. There are 45 wooden spindles (1 + 2 + 3 . . . + 9 = 45), and the child learns to count them out, placing the appropriate number in each compartment in the box. As with other materials, the child should notice if he or she makes an error, because the child will not have the correct number available for another compartment.

With the Spindles, quantity is introduced in a new way, with "9" being nine individual objects grouped together. This way of thinking about numbers was gradually introduced, from the Red Rods, to the Number Rods (alternating blue and red units), to the Spindles. After the child has mastered the Spindle Box, different kinds of counters, such as small cubes or sticks, are placed in appropriate groupings beside numbers. Importantly, these objects do not have some other function; toys, for example, are not used to count in Montessori. Research by Judy DeLoache suggests that Montessori programs are on the right track in not mixing toys with symbolic materials. When an object is both a symbol and something to play with, children have trouble seeing it as a symbol (DeLoache, 2000). For example, if young children are allowed to play with a dollhouse that is also a model for a larger space, they have more trouble using the dollhouse as a symbol for the larger space than they do when they do not play with it. People are sometimes disturbed that children are not permitted to play with Montessori materials, for example to build a house from the Brown Stair. DeLoache's research suggests that in fact such play might inhibit children's recognition of the underlying concepts intended to be conveyed by these materials.

From the Spindle Boxes, children move on to use Golden Beads that come in units, 10 bars, 100 squares, and 1,000 cubes, and later, Bead Bars of two to nine differently colored glass beads and then Bead Chains that are made by chaining together the Bead Bars (see Figure 2.6). The 10-bead bar holds 10 golden-orange beads, the 9-bead bar holds 9 dark blue ones, the 8-bead bar holds 8 lavender beads, and so on. In essence, these bars of beads are like miniature versions of the number rods without alternating colors.

In chapter 1, I mentioned that Montessori education is based on empirical observation of children, and that Dr. Montessori adjusted what she presented to children based on how children responded to the materials. The beads are an example of this. Dr. Montessori initially intended the glass bead material only for Elementary children, but she noticed 4-year-olds watching with great interest when older children used it. She presented the material to younger children, and seeing that it effectively presented mathematical concepts to younger children and that younger children were interested, she placed the bead material in the Primary classroom as well. With these materials, children in Montessori Primary classrooms perform mathematical operations that many would think too advanced for them, such as adding and subtracting four-digit numbers. Because the children seemed interested, Dr. Montessori saw no harm in this, and indeed believed other school systems hold children back. However, some (including Piaget and other of her important contemporaries) believed Montessori presents concepts too early and have dismissed Montessori on that basis. The Mil-

FIGURE 2.6. The Beads

waukee study showing that high school students who previously were in Montessori programs performed significantly better on math and science tests than other children suggests that the system is effective.

In all these exercises, movement of the body is closely entwined with cognition, since every learning exercise involves materials that children touch and move, bringing concrete embodiment to abstract concepts. Abstract concepts are embedded in the Montessori math materials, and even in the Sensorial Materials that lead to them. The extent to which the underlying abstractions are conveyed through using the Montessori materials is a topic in need of empirical study. Some research does suggest that hand movements are a privileged means for understanding symbols.

Research on Gesture and Symbolic Understanding

Gesture appears to aid symbolic understanding even in infancy. Infants learning American Sign Language (ASL) as their sole language have been shown to name objects with gestures earlier than children learning only spoken language can name objects with words. For example, in one study, children learning ASL reached the 10-item vocabulary point at 13 months, whereas hearing children learning spoken language reached the 10-item milestone at 15 months (Bonvillian, Orlansky, Novack, & Folven, 1983; Folven & Bonvillian, 1991).

The claim that children have privileged symbolic understanding via sign language is controversial, because children learning both ASL and spoken language simultaneously learn the two languages at the same rate (Petitto et al., 2001). In this study, children's ASL was not more advanced than their spoken language. However, such findings might be biased against ASL learning because for bilingual (hearing) children, exposure to spoken language might be greater than is exposure to sign.

If, when input is equal, ASL signs are learned earlier, it might in part be because some signs are iconic (at least more so than words), and thus align thought and action more closely than do words. Linda Acredolo and her colleagues have developed a set of very iconic signs and have found that infants learn these signs earlier than words, even when both types of symbols are presented to children at the same rate (Acredolo, Goodwyn, Abrams, & Hanson, 2002). For example, if a parent consistently uses both a flapping gesture and the word "bird" to name birds, her child will use a flapping gesture to name a bird about a month earlier, on average, than the child will use the word "bird" (Goodwyn & Acredolo, 1993).

Another study showed that parents' frequent use of gestures in communication with their children even hastened their spoken language development (Goodwyn, Acredolo, & Brown, 2000). One group of parents was trained to use gestural communication with their 11-month-olds, a second was trained to make special efforts at using verbal labels, and a third group was left to behave as usual. The children's language abilities were tested several times from 15 to 36 months of age. The gestural training group was found to excel on the majority of the measures of language acquisition that were administered during the two years of the study. However, by 36 months of age the differences were less pronounced, echoing the notion that the long-term outcomes of basic developmental processes may not be importantly altered by some variations in experience.

Susan Goldin-Meadow and her colleagues observed a close relationship between children's use of gesture and the transition from one- to two-word speech (Goldin-Meadow & Butcher, 2003). Two-word speech often expresses two different ideas, such as "want" and "apple." During the transition to two-word speech, children sometimes make gestures that are redundant with speech, thus expressing a single idea, for example, flapping their hands while saying "bird." At other times during this transitional period, children make gestures that convey a different meaning from their speech, for example, pointing at an apple while saying "eat." For the children studied, use of gesture-speech combinations conveying two distinct ideas always preceded their first two-word utterance by an average of 2.3 months. Furthermore, the age at which children produced their first distinct gesture-speech combination correlated very highly with the age at which they produced their first two-word utterance ($r = 0.90$). Importantly, gesture-speech combinations that conveyed a single idea were not related to two-word utterances. The gestural modality may have allowed thoughts to be conveyed earlier than they could be conveyed in speech, and using such combinations in gesture may have even facilitated their use in spoken language.

Another example of gesture possibly aiding symbolic cognition in young children occurs in the work of the psychologist Michael Tomasello and his colleagues, who found that children can interpret symbols designated by actions earlier than they understand symbols designated by models (Tomasello, Striano, & Rochat, 1999). In this research, children were taught to select an object and then put it down a chute. Which object to select was designated in one of two ways: via an adult pointing out a small model of the object, or via an adult carrying out the action typically performed with that object. For example, a hammer could be designated by a miniature hammer or by a hammering gesture. Even the youngest children tested (18 months) performed better in response to gestures that conveyed how an object would be used than to miniature models of those objects. In other words, they were more apt to put the full-sized hammer down the chute after the experimenter pretended to hammer via hammering gestures with an imaginary hammer than after the experimenter pointed to a miniature hammer.

In sum, symbolic understanding can be effectively communicated both by and to children through gesture even before it can be communicated verbally or even by physical models. Hand movements that convey meaning might be privileged for children relative to spoken words that convey meaning.

Rendering the Symbolic Concrete: More Montessori Math

Many Montessori materials are designed to expose the child's hand to abstract concepts, which are then gradually revealed to the mind. The se-

FIGURE 2.7. The Binomial Cube

quence presented earlier from Pink Tower to Bead (which continues further) is one example of this. Another example is the Binomial and Trinomial Cubes (see Figures 2.7 and 2.8). These materials are wooden boxes with hinged sides that open to expose a set of blocks inside. The blocks fit perfectly inside the wooden box. Embodied in those pieces is the algebraic formula for finding the volume of a cube. For example, for the Trinomial Cube, the sides are of length a + b + c: $(a + b + c)^3 = (a^3 + 3a^2b + 3a^2c + b^3 + 3ab^2 + 3b^2c + c^3 + 3ac^2 + 3bc^2 + 6abc)$. This is because the small blocks that fit inside the cubes have sides of lengths a, b, and c. The red cube is a^3, the blue cube is b^3, and the yellow cube is c^3. There are 3 cubes that embody a^2b, which are red on some sides and blue on others. And so on. The Binomial Cube works in the same way, but presents the simpler eight-part binomial formula.

In the Primary classroom, the Binomial Cube is a Sensorial Material and

FIGURE 2.8. The Trinomial Cube

is like a puzzle in that one fits the pieces together. When children are reintroduced to the Binomial Cube in Elementary, they are specifically shown how it embodies the binomial formula. The Montessori material is a hands-on instantiation of what the formula represents. These materials can seem like small miracles to those of us who went through traditional math courses, plugging numbers into formulas often without understanding what the formulas represent. More recently, traditional schools are discovering and using similar materials on occasion. Manipulatives can vary in their usefulness, with some studies showing that children sometimes make interpretations very different from what adults intended (DeLoache, Uttal, & Pierroutsakos, 1998). At other times, as much of the research presented here suggests, they can be used successfully (e.g., Sayeki, Ueno, & Nagasaka, 1991). More research should be done to investigate what types of manipu-

FIGURE 2.9. Botany Work

latives are beneficial to children learning mathematical concepts. Research should also be done on Montessori math materials specifically, to determine whether the underlying mathematical purpose of the materials is conveyed. The materials clearly involve movement that is aligned with cognition, which research suggests would be associated with better learning.

Movement in Other Domains in Montessori Education

Movement is also incorporated into other areas of the Montessori curriculum, such as botany and geography. For example, while learning the parts of a plant, children draw the plant parts (see Figure 2.9); when learning the countries of Europe, children first learn simply to put the countries in place like pieces of a puzzle. They trace the outlines of the wood pieces representing countries with their finger and then later make a paper map, trac-

ing the outlines onto paper with a pencil. They then color in the pencil outlines, label the countries with labels that they write, and place the appropriate national flags on the countries. A great deal of their learning geography, then, involves movement that is consistent with thought: move the puzzle pieces, trace the country, draw the country, color the country in, and so on. Although fundamentally based on textbooks and lectures, traditional schooling can incorporate such activities; Montessori education is infused with them, and textbooks and lectures are virtually absent.

In Montessori Elementary classrooms, children continue to physically move about as they carry out much of their work. By the later years, as children carry out independent research projects, they do spend increasing amounts of time at tables reading and writing. Still, Elementary children have hands-on materials for most topics, including math, science, music, art, grammar, and learning about other cultures. For example, Elementary school children investigate how people over the ages and in different climates have solved the basic problems of getting food, shelter, and clothing. In doing so, they create charts and make models, for example of houses around the world. Their work continues to involve the hand and connects back to the more basic work done much earlier. For example, through their earlier work with maps in Primary, Elementary school children have a sense of where the countries whose houses they are researching are located. In other work they study biomes (again by drawing maps), so they have a sense of the varying climates of those regions.

In traditional schooling, children might occasionally have projects where they work with their hands (and these projects are usually well regarded by children), but much of their learning is from listening to the teacher, taking notes, and memorizing for tests. In contrast, in Montessori, the Elementary teacher presents stories about how people live that inspire the children to go find out more, as discussed in chapter 4. Children are not assigned to make models of houses from around the world; they decide to, as is discussed in chapter 3. They do not make those models because they will be tested on them and graded; they make them because they are motivated to learn, as discussed in chapter 5. Thus in Montessori the hands-on activities are rooted in a fundamentally different soil than are similar projects that one sometimes sees enacted in traditional schools.

Montessori involves movement even in reading and vocabulary building, generally thought of as tasks for which one sits still. As they learn the vocabulary for new objects, children move cards from a storage box and place them by the objects they name. Dr. Montessori noted that through this process, children were inherently learning what a noun is, and she reasoned that other parts of speech could also be learned via such exercises. The Command Cards allow this. These are cards with commands written on them, such as "walk," "sing," and "jump." Children read the commands and execute the action, so the overarching concept of "verb" is conveyed. Adverbs are embodied in commands to "Tiptoe rapidly to the door, then tiptoe slowly back to your seat." Children practice tiptoeing rapidly, then tiptoeing slowly, thus moving as they commit to mind what an adverb is. They learn about the importance of conjunctions by carrying out commands in which conjunctions are present and missing.

Acting out what one reads sharpens one's attention to words and their precise meaning, which is another goal of the Command Cards. Phrases such as "Close the blinds; open the front door; wait a moment; then rearrange everything as before" or "Very politely ask eight of your companions to leave their chairs, form double file in the center of the room, and march back and forth on tiptoe, making no noise" convey precise meanings. Although it is ultimately an empirical question, it fits with the research presented earlier and seems logical that one would be more apt to notice exactly what a word means when one has to do what it says than when one simply reads it. As a teacher of writing, I know the problem in many a student's writing is not paying close attention to what words mean, and exercises that get students to pay attention to meaning (because they have to carry out actions based on them) might serve that end.

Going Out

In addition to moving about in the classroom as they learn, an integral part of children's Montessori education involves moving out of the classroom. For example, children learn about trees or birds or flowers in the classroom (from cards, charts, books, and models), and these provide an objective for their walks. Children can go out to find that which they have seen in the classroom. The objects can be brought back into the classroom for classification and further study. Walking outside with an educational purpose, to find objects in the world, is incorporated into the program.

Montessori children not only go for walks to learn about nearby surroundings, but also to venture farther afield to learn about the world. Going out of the classroom takes on a new character in Elementary, driven by the children's personal interests and goals because they are becoming more independent. A child (or more likely a small group of children: by Elementary children are usually very socially inclined) who is interested in learning more about birds might visit a bird sanctuary, an ornithologist, and a natural history museum as part of the research for a report on birds that she (or they) will later give to the class. Unless the school is situated in a safe place, an adult, usually a parent volunteer or class assistant, accompanies children on these trips. Any given child might leave the classroom twice a

month, for a half or whole day, on such a venture, called a "Going Out" trip. Elementary children thus move on a grand scale, out of the classroom, as part of their learning.

Recess and Physical Education

In what might strike people as a bizarre twist, Dr. Montessori argued against having recess as part of the Montessori school day. Her reasons for this are quite clear in her books: it interrupts concentration, and it is unnecessary. The concentration issue is considered first.

Recess time could be detrimental in Montessori because for any given child on a given day a clock-imposed recess time might well come at a moment of intense concentration on work. Of course such concentration must be broken at some times, notably the end of the school day, but Dr. Montessori's goal was to minimize these interruptions:

> Montessori schools have proved that the child needs a cycle of work for which he has been mentally prepared; such intelligent work with interest is not fatiguing, and he should not be arbitrarily cut off from it by a call to play. Interest is not immediately born, and if when it has been created the work is withdrawn [for recess or any other adult-imposed break], it is like depriving a whetted appetite of the food that will satisfy it. (1948/1967, p. 118)

Any scheduled events, from recess to extracurriculars, could easily break children's concentration. Montessori teachers who have experienced classrooms deep in concentration have expressed that on days when the children know they will be interrupted (for a field trip or even a regularly scheduled art class which some Montessori schools add), they do not settle into their work as deeply as they do on mornings when nothing is scheduled.

A second reason Dr. Montessori did not include recess in her programs is that she saw it as unnecessary. In traditional schools, recess serves physical, mental, and social functions. Physically, it may well be necessary, because children are asked to sit and listen much of the time and sitting still can be tiring, even sometimes for adults. Like a stretch break in the middle of a one-hour lecture, recess can give the child a chance to recuperate attention by allowing the body to move from a sedentary position. In Montessori classrooms, children are constantly on the move. Even when they sit for lessons, the lessons keep the child active. Because children are constantly moving their bodies to do work in Montessori classrooms, Dr. Montessori saw recess as physically unnecessary. "The mental life shown by our children brings the whole of their musculature into constant use" (Montessori, 1967a, p. 145).

The mental recreation function of recess in traditional schools might also be unnecessary in Montessori because children freely choose their work and hence are likely to be interested in it (see chapter 4 on interest). In addition, when a child needs a break from work in Montessori, the child can take it. Children can stop and daydream for a time, pick up a recreational book, engage in free drawing, perhaps go outside and play, and so on. Of course, children are not free to abandon their education, and the teacher is responsible for noticing if a child is not using time wisely and intervening if needed. But children are free to make such choices as long as they behave responsibly, and thus the mental-break function of recess may be unnecessary in Montessori.

Regarding the social function of recess, in Montessori classrooms children can be as social as they like. As long as they are learning, they are allowed to chat with friends while they are working, and they are allowed to work with friends. The fact that social interactions in Montessori occur within a structured classroom environment rather than on playgrounds might also help children establish positive social relationships. Bullying and teasing tend to be problems of the school playground, where adult supervision is more difficult. These are all interesting issues for further research.

In sum, Dr. Montessori saw recess both as an impediment to concentration and as unnecessary, since the functions it serves in traditional schools (exercise, a mental and physical break from the status quo, and social time) are already served within the Montessori classroom. Montessori schools that closely follow Dr. Montessori's program therefore do not always have recess; those that do may well have it in only in response to parent pressures, or as a routine that is hard to eliminate once instituted.

How might one allow for more gross motor outdoor activity without recess? This is a particularly important issue in light of rising obesity rates among children in the United States. Ideally, a Montessori school has an outdoor area and some sports equipment, and a child might choose to play soccer or baseball for up to 20 or 30 minutes of the school day. To get a group sport going, the child has to gather together a group of willing others to go play, which is itself a learning opportunity. Children who have not been good social partners get feedback, if other children do not choose to go with them. Physical education or recess time is a choice children can make, rather than something imposed by the clock and adults' schedules. After-school sports programs can of course also serve this function, as they often do in Europe. Ultimately, the responsibility that children get adequate exercise and have a healthy diet lies with the parents. Perhaps that is where

it best resides regardless: although traditional schools today provide physical education, childhood obesity is perceived to be a major national health problem.

The final topic discussed in this chapter is the potential impact of movement on how teachers teach.

Creating a Learning Environment through Gesture

Additional work by Susan Goldin-Meadow and her colleagues suggests that children's gestures can also be subconsciously interpreted by teachers, causing them to teach differently. An educational system that capitalizes on this by bringing gestures out might be beneficial. Montessori teachers watch children move as they learn, and it is possible that those movements convey important information to teachers.

Gesture Leads Cognition: Gesture-Speech Mismatch

Goldin-Meadow and her colleagues have shown that in several domains movement not only assists cognition, but leads it as well. In other words, children reveal understandings in gesture that they cannot yet reveal in speech. Studies in the domains of conservation and mathematical understanding will be used to illustrate this.

Piaget's classic conservation tasks test children's understanding that superficial changes do not create deep ones. For example, in a Piagetian number conservation task, an experimenter lays out two rows of five checkers each. At first the checkers are evenly spaced, and the experimenter asks the child which row has more. A child of 4 or 5 can normally tell you the rows are the same. The experimenter then spreads one of the rows out, so it still contains five checkers, but now is perceptually longer than the other row. The experimenter again asks which row has more (or whether they are both the same). Children under 6 years of age often make a conservation error, claiming that the spread-out row has more. This happens even if the items involved are money and the child gets to take them home, and even if the perceptually shorter row actually has more. Children will claim they would rather take home five pennies than six, if the row of five pennies is perceptually longer than the row of six.

Goldin-Meadow and her colleagues (Church & Goldin-Meadow, 1986) noticed an interesting aberration when some children solve these tasks. At the same time as the child verbally gives the wrong answer, claiming the spread-out row has more,

> the child moves his pointing finger between the first and second checker in the spread-out row and the first checker in the unspread-out row, and then continues pairing the checkers in the two rows. In his speech, the child focuses on the fact that the experimenter spread the checkers out. In his gesture, however, the child demonstrates some understanding of the fact that the checkers in the two rows can be paired with one another, thus demonstrating an incipient understanding. (Goldin-Meadow, 2002, p. 137)

The hand thus leads the mind; the child tells it in gesture before he can tell it in words. In addition, a child who gives the wrong verbal answer but the right one in gesture today will, in the coming days, begin to give the right verbal answer as well. Movement thus leads cognition.

The same sequence has been noticed in conservation of liquid tasks (Church & Goldin-Meadow, 1986) and reasoning about arithmetic problems (Perry, Church, & Goldin-Meadow, 1988). For example, in one study asking children to solve number equivalence problems such as $4 + 7 + 5 = 4 + —$, some children's gestures matched their speech and others' did not (Alibali & Goldin-Meadow, 1993). An example of a gesture that matched speech would be "if a child [who incorrectly answered '16'] said 'I added the 4, the 7, and the 5' . . . while pointing to the left 4, the 7, and the 5" (p. 485). This child is incorrect but consistent across speech and gesture. If tested at a later time, this same child might still say "16" but indicate the correct solution with gestures, for example, point to the left 4, 7, and 5 (totaling 16), and then produce a flick-away movement near the right 4, which needs to be subtracted from 16 to arrive at the correct solution. In fact, 44% of the problem-solving strategies children expressed in this study were expressed in gestures that did not match their speech and that were in fact more advanced than their speech.

Children's emergent knowledge is thus sometimes expressed with the hands even before it is expressed with speech. Other research has shown that this pattern is not limited to children. Adults also use gestures conveying how they are going to solve a problem, even when they do not express those strategies in speech (Goldin-Meadow, 2002).

Gesture-Speech Mismatches and Instruction

Children whose gestures do not match their speech are particularly apt to benefit from instruction (Perry et al., 1988; Perry & Elder, 1997). In the experiment already mentioned (Alibali & Goldin-Meadow, 1993), fourth-graders who had failed a pre-test of 10 mathematical equivalence problems and naturally gestured while trying to solve them were randomly assigned

either to a group that received instruction or to a control group that did not. They were then given 12 addition equivalence problems to solve, like the one shown earlier. For each problem, children in the instruction group were given feedback emphasizing equivalence:

> That's a good try, but it's not the right answer because it doesn't make both sides equal. . . . It seems to me that you were thinking of the equal sign as an instruction to add up all the numbers in the problem, but that isn't really what the equal sign means. Really the equal sign means "is the same as." It tells you to make both sides of the problem the same. (p. 482)

A test of understanding of mathematical equivalence was given after the training. Not surprisingly, only children who received instruction did better at the post-test than they had at pre-test. But among those who received instruction, those whose gestures and speech did not match during the pre-test were especially likely to perform better on the post-tests. It appeared that these mismatching children were in some sense entertaining the correct method, as indicated by their gesture, and that instruction served to bring the method to the fore (Perry et al., 1988).

Teachers Appear to Unconsciously Notice Gesture

Do teachers naturally capitalize on gesture-speech mismatches in giving instruction? To address this question, eight teachers were recruited to teach math-equivalence problems to third- and fourth-grade children who had previously failed on such problems (Goldin-Meadow & Singer, 2003). Whereas in the prior study all children were given the same instruction by an experimenter, in this study the teachers' instructions were unscripted. At issue was whether teachers teach differently to students whose gestures and speech do not match. Teachers were told to put the first problem on the board, ask the child to solve it, and explain the solution. Each teaching session was videotaped. Children's gestures were coded as matching or not matching their speech, as were the number of different instructional strategies employed by the teacher.

The teachers showed twice as many different types of problem-solving strategies, on average, to the children whose gestures and speech did not match as to the children whose gestures and speech matched. Because children in both groups expressed a similar set of strategies overall, the change in teaching apparently stemmed from the teachers' noticing the gesture-speech mismatch. Children appear to create their own instructional environment by their gesturing.

Other research has shown that what the teachers were doing with the mismatch children—presenting an array of different strategies rather than just one—facilitates the understanding of new concepts (Perry & Elder, 1997; Siegler, 1994). In keeping with this conclusion, the children who were shown the greatest variety of strategies (the gesture-speech mismatch group) performed the best on the post-test. Of course, we cannot know for sure in this case that the teaching was responsible, since we know that the children who produce mismatches are more likely to advance regardless. Still, it appears that teachers are sensitive to speech-gesture mismatches in natural situations, and that they do vary their teaching accordingly.

As Goldin-Meadow has noted, gesture may be one of the best ways for teachers to see where the upper edge of the child's competence lies. Seeing how children use their hands may allow teachers to direct their teaching strategies to the top of what the famous developmental theorist Lev Vygotsky (1978) termed the child's "zone of proximal development"—the set of competencies the child does not show when working alone, but does show when working with the assistance of a more competent other. Apparently children's gesture-speech mismatches did indicate to teachers that children were ready to learn, teachers responded by providing more varied learning strategies to such children, and those children profited from the instruction and showed the greatest gains in learning. Teaching methods that capitalize on this by engaging children's hands in the learning process would be expected to enable better learning.

Chapter Summary

Even scientists and educators have failed to notice the great importance of movement in human development.
—MARIA MONTESSORI (1966, p. 100)

[The child needs] activity concentrated on some task that requires movement of the hands guided by the intellect.
—MARIA MONTESSORI (1966, p. 138)

Dr. Montessori was deeply concerned with the relationship between movement and cognition, and advised that from birth infants be given opportunities and incentives to move their bodies in purposeful ways. Children in Montessori classrooms freely move about, working at tables and at small rugs on the floor, allowing for far more movement than in traditional classrooms, where children are often seated at their desks until recess. In addition, most Montessori work involves manipulating objects with one's hands

and even moving one's whole body as part of the particular task. Children carry large maps to rugs, remove and trace the countries, carry and set flags on those countries, and color in small pictures of the flags. Children handle the math materials and come across the basic concepts of arithmetic. Cognition is embedded in action, by virtue of learning through these materials. Hand gestures also help us to understand others' thought processes, and with Montessori materials, hands are constantly in motion, which might allow for better communication at that level. Children see the hands of the teachers as they present those materials, and the teachers see the hands of the children as they enact the exercises.

The integration of movement and cognition in Montessori classrooms contrasts sharply with traditional education, in which children sit at desks and do much of their learning in workbooks. Because there is little for the hand to do besides write letters and numbers, traditional education cannot easily capitalize on the findings that movement and gesture both reveal and lead cognition.

Dr. Montessori's respect for movement was profound, as she saw society as founded upon movement and civilization as founded on the particular movements of human hands: "The skill of the hand is bound up with the development of [the] mind, and in the light of history we see it connected with the development of civilization . . . all the changes in [our] environment are brought about by hands" (1967a, pp. 150–51).

Because humans have free will, we decide how we will move our hands and our bodies. Another very important educational insight of Montessori, and the topic of the next chapter, is the importance of free choice to learning and well-being.

Maria Montessori, Barcelona, 1926. Photograph courtesy of the Archives of the Association Montessori Internationale.

MONTESSORI

THE SCIENCE BEHIND THE GENIUS

Angeline Stoll Lillard

Photographs by An Vu

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