Constructionism in Practice
Designing, Thinking, and Learning in a Digital World

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The publisher has gone to great lengths to ensure the quality of this reprint but points out that some imperfections in the original may be apparent.

1
A Word for Learning

Seymour Papert

Why is there no word in English for the art of learning? Webster says that the word *pedagogy* means the art of teaching. What is missing is the parallel word for learning. In schools of education, courses on the art of teaching are often listed simply as "methods." Everyone understands that the methods of importance in education are those of teaching—these courses supply what is thought to be needed to become a skilled teacher. But what about methods of learning? What courses are offered for those who want to become skilled learners?

The same imbalance can be found in words for the theories behind these two arts. "Theory of Instruction" and "Instructional Design" are among many ways of designating an academic area of study and research in support of the art of teaching. There are no similar designations for academic areas in support of the art of learning. Understandably: The need for such names has not been felt because there is so little to which they would apply. Pedagogy, the art of teaching, under its various names, has been adopted by the academic world as a respectable and important field. The art of learning is an academic orphan.

One should not be misled by the fact that libraries of academic departments of psychology often have a section marked "learning theory." The older books under this heading deal with the activity that is sometimes caricatured by the image of a white-coated scientist watching a rat run through a maze; newer volumes are more likely to base their theories on the performance of computer programs than on the behavior of animals. I do not mean to denigrate such books—I am myself the co-author of one and proud of it—but only to observe that they are not about the art of learning. They do not, for instance, offer advice to the rat (or the computer) about how to learn, although they have much to say to the psychologist about how to train a rat. Sometimes they are taken as a basis for

training children, but I have not been able to find in them any useful advice about how to improve my own learning.

The unequal treatment by our language of the arts of learning and of teaching is visible in grammar as well as in vocabulary. Think, for example, of parsing the sentence, "The teacher teaches a child." *Teacher* is the active subject of the sentence; *child* is the passive object. The teacher does something to the learner. This grammatical form bears the stamp of school's hierarchical ideology in representing teaching as the active process. The teacher is in control and is therefore the one who needs skill; the learner simply has to obey instructions. This asymmetry is so deeply rooted that even the advocates of "active" or "constructivist" education find it hard to escape. There are many books and courses on the art of constructivist teaching, that talk about the art of setting up situations in which the learner will "construct knowledge"; but I do not know of any books on what I would assume to be the more difficult art of actually constructing the knowledge. The how-to-do-it literature in the constructivist subculture is almost as strongly biased to the teacher side as it is in the instructionist subculture.

A first step toward remedying these deficiencies is to give the missing area of study a name so that we can talk about it. Besides, it is only respectful to do this: Any culture that shows proper respect to the art of learning would have a name for it. In *Mindstorms* I proposed a word that did not catch on, but since I believe that there is more cultural readiness for such a word today, I shall try again—always bearing in mind that my principal goal is less to advocate this particular word than to emphasize the need for one. If the culture is really ripe for such a word, many people will throw in their own words (perhaps simply by quietly using them), and eventually one will take root in the soil of the language. Linnaeus, the father of botanical terminology, could decide to call a familiar white flower *Bellis perennis*, but the common language calls it a daisy, ignoring the Latin name just as it ignores the botanist's insistence that a daisy is an "inflorescence" and not a flower at all. A person can propose; "the culture" or "the language" disposes.

In any case, to illustrate the gap in our language and my proposal for filling it, consider the following sentence: "When I learned French I acquired _____ knowledge about the language, _____ knowledge about the people, and _____ knowledge about learning." *Linguistic* and *cultural* would fill in the first two blanks with no problems, but the reader will be hard put to think up a word to fill in the third blank. My candidate is *mathetic*, and I thereby make restitution for a semantic theft perpetrated by my professional ancestors, who stole the word *mathematics* from a family of Greek words related to learning. *Mathmatikos* meant "disposed to learn"; *mathema* was "a lesson," and *manthanein* was the verb "to learn." Mathematicians were so convinced that theirs was the only true learning that they felt justified in appropriating the word, and succeeded so well that the dominant connotation of the stem *math-* is now that

stuff about numbers they teach in school. One of the few traces of the original sense of the root retained by current English is "polymath." This is not a person who knows many kinds of mathematics, but one who has learned broadly. Following my proposal, I would use the noun *mathetics* for a course on the art of learning, as in: "Mathetics (by whatever name it will come to be known) is even more important than mathematics as an area of study for children."

A comparison with another Greek term borrowed for talking about mental process will clarify the intended meaning of "mathetics" and perhaps support its "sound" and "feel." *Heuristics*—from the same stem as Archimedes' cry "Eureka!"—means the art of intellectual discovery. In recent times it has been applied specifically to discovering solutions of problems. Thus mathetics is to learning what heuristics is to problem solving.

Although the idea of heuristics is old—it goes back at least to Descartes and, if one stretches it a little, to the Greeks—its influence on contemporary educational thinking is mainly due to mathematician George Polya, who is best known through his book, *How to Solve It.* His theme runs parallel to my complaint that school gives more importance to knowledge about numbers and grammar than to knowledge about learning, except that in place of the word *learning*, Polya says "principles of solving problems." I would echo this wholeheartedly: In school, children are taught more about numbers and grammar than about thinking. In an early paper that supported and extended Polya's ideas, I even formulated this as a challenging paradox:

> It is usually considered good practice to give people instruction in their occupational activities. Now, the occupational activities of children are learning, thinking, playing, and the like. Yet, we tell them nothing about those things. Instead, we tell them about numbers, grammar, and the French Revolution; somehow hoping that from this disorder the really important things will emerge all by themselves. And they sometimes do. But the alienation-dropout-drug complex is certainly not less frequent. . . . The paradox remains: why don't we teach them to think, to learn, to play? (Papert, 1971, chap. 2, p. 1)

Traditional education sees intelligence as inherent in the human mind and therefore in no need of being learned. This would mean that it is proper for school to teach facts, ideas, and values on the assumption that human beings (of any age) are endowed by nature with the ability to use them. Polya's challenge started with the simple observation that students' ability to solve problems improved when he instructed them to follow such simple rules as, "Before doing anything else, spend a little time trying to think of other problems that are similar to the one in hand." He went on to develop a collection of other heuristic rules in the same spirit, some of which, like this one, apply to all kinds of problems and some to specific areas of knowledge, among which Polya himself paid the most attention to mathematics.

Another typical example of Polya's type of rule adapts the principle of "divide and conquer." Students often fail to solve a problem because they insist on trying to solve the whole problem all at once; in many cases they would have an easier time of it if they were to recognize that parts of the problem can be solved separately and later be put together to deal with the whole. Thus the Wright Brothers had the intention from the beginning of building a powered airplane that could take off from a field, but had they tried to build such a thing for their first experiments, they would very likely have come to the same gory end as many of their predecessors. Instead, they solved the problem of wing design by inventing and building a wind tunnel in which they tested wing sections. Then they built a glider that would take off from a track lined up with the wind in a place where winds were ideal. Independently of all this they also worked on an engine. In this way they gradually conquered all the problems.

Polya wished to introduce into education a more explicit treatment of the principles of what is often called "problem solving." In the same way, I want to introduce a more explicit treatment of the principles of learning. But thinking about heuristics helps to explain the idea of mathetics in another way as well. By offering my own unorthodox explanation of why heuristic principles help students, I shall try to bring out a contrast between *heuristics* and *mathetics.*

I believe that problem solving uses processes far more subtle than those captured in Polya's rules. This is not to say that the rules are not valuable as aids to solving problems, but I do think that their most important role is less direct and much simpler than their literal meaning. Attempting to apply heuristic rules checks students in the rush to get done with a problem and get on with the next. It has them spend more time with the problem, and my mathetic point is simply that spending relaxed time with a problem leads to getting to know it, and through this, to improving one's ability to deal with other problems like it. It is not using the rule that solves the problem; it is thinking about the problem that fosters learning. So does talking about the problems or showing them to someone else. What is mathetic here is the shift of focus from thinking about whether the rules themselves are effective in the immediate application to looking for multiple explanations of how working with the rules can contribute in the longer run to learning. To make the point in a possibly exaggerated form, I suggest that any kind of "playing with problems" will enhance the abilities that lie behind their solution.

This interpretation of why heuristic methods work highlights several mathetically important themes, each of which points to a way in which school impedes learning and to some good advice about how to do it better.

To begin with, the theme of "taking time," just mentioned in connection with Polya, is well illustrated by a passage from a book whose name has more than once raised eyebrows when I quoted it in academic circles: the best-selling, *The Road Less Traveled*, by psychiatrist M. Scott Peck (1980). I read the book in the first place for the same reason that I have made alliances with LEGO and

Nintendo, which has also caused some academically pure and politically correct eyebrows to rise at the idea of having any connection with people who make money. Anyone who can draw as many people into situations related to learning as Peck, LEGO, or Nintendo knows something that educators who have trouble holding the attention of 30 children for 40 minutes should want to learn.

Here is what Peck (1980) had to say about taking time:

> At the age of thirty-seven I learned how to fix things. Prior to that time almost all my attempts to make minor plumbing repairs, mend toys or assemble boxed furniture according to the accompanying hieroglyphical instruction sheet ended in confusion, failure and frustration. Despite having managed to make it through medical school and support a family as a more or less successful executive and psychiatrist, I considered myself to be a mechanical idiot. I was convinced I was deficient in some gene, or by curse of nature lacking some mystical quality responsible for mechanical ability. Then one day at the end of my thirty-seventh year, while taking a spring Sunday walk, I happened upon a neighbor in the process of repairing a lawn mower. After greeting him I remarked, "Boy, I sure admire you. I've never been able to fix those kind of things or do anything like that." My neighbor, without a moment's hesitation, shot back, "That's because you don't take the time." I resumed my walk, somehow disquieted by the gurulike simplicity, spontaneity and definitiveness of his response. "You don't suppose he could be right, do you?" I asked myself. Somehow it registered, and the next time the opportunity presented itself to make a minor repair I was able to remind myself to take my time. The parking brake was stuck on a patient's car, and she knew that there was something one could do under the dashboard to release it, but she didn't know what. I lay down on the floor below the front seat of her car. Then I took the time to make myself comfortable. Once I was comfortable, I then took the time to look at the situation. I looked for several minutes. At first all I saw was a confusing jumble of wires and tubes and rods, whose meaning I did not know. But gradually, in no hurry, I was able to focus my sight on the brake apparatus and trace its course. And then it became clear to me that there was a little latch preventing the brake from being released. I slowly studied this latch until it became clear to me that if I were to push it upward with the tip of my finger it would move easily and would release the brake. And so I did this. One single motion, one ounce of pressure from a fingertip, and the problem was solved. I was a master mechanic!
>
> Actually, I don't begin to have the knowledge or the time to gain that knowledge to be able to fix most mechanical failures, given the fact that I choose to concentrate my time on nonmechanical matters. So I still usually go running to the nearest repairman. But I now know that this is a choice I make, and I am not cursed or genetically defective or otherwise incapacitated or impotent. And I know that I and anyone else who is not mentally defective can solve any problem if we are willing to take the time. (pp. 27–28)

Give yourself time is an absurdly obvious principle that falls equally under heuristics and mathetics. Yet school flagrantly contravenes it by its ways of chopping time: "Get out your books . . . do 10 problems at the end of chapter

18 . . . DONG . . . there's the bell, close the books." Imagine a business executive, or a brain surgeon, or a scientist who had to work to such a fragmented schedule.

This story speaks as poignantly about a second theme—talking—as about time. Peck does not say this explicitly, but one can guess that he would have had the epiphany about taking his time at an earlier age than 37 had he talked more often to more people about his and their experiences with mechanical problems. A central tenet of mathetics is that good discussion promotes learning, and one of its central research goals is to elucidate the kinds of discussion that do the most good and the kinds of circumstances that favor such discussions. Yet in most circles talking about what really goes on in our minds is blocked by taboos as firm as those that inhibited Victorians from expressing their sexual fantasies. These taboos are encouraged by school, but go far beyond it, and point to ways in which our general culture is profoundly "antimathetic."

An extreme example will vividly illustrate the antimathetic process that exists in many more subtle, but destructive, forms in school. The incident took place in a "resource room," where children diagnosed as having a learning disability spend part of their day. Third grader Frank was one of them.

An aide gave Frank a set of sums to do on a piece of paper. I knew the child bitterly hated doing sums on paper, although under other conditions he could work quite successfully with numbers. For example, I had seen him do quite impressive calculations of how many and what shapes of LEGO pieces he needed for a job he wanted to do. To deal with the school demand to calculate with numbers in isolation from real needs, he had a number of techniques. One was to use his fingers, but his teacher had observed this and ruled that it was not allowed. As he sat in the resource room, I could see him itching to do finger manipulations. But he knew better. Then I saw him look around for something else to count with. Nothing was at hand. I could see his frustration grow. What could I do? I could pull rank and persuade the aide to give him something else to do or allow finger counting. But this wouldn't solve any real problems: Tomorrow he would be back in the same situation. Educate the aide? This was not the time or place. Inspiration came! I walked casually up to the boy and said out loud: "Did you think about your teeth?" I knew instantly from his face that he got the point, and from the aide's face that she did not. "Learning disability indeed!" I said to myself. He did his sums with a half-concealed smile, obviously delighted with the subversive idea.

In a classic joke, a child stays behind after school to ask a personal question. "Teacher, what did I learn today?" The surprised teacher asks, "Why do you ask that?" and the child replies, "Daddy always asks me and I never know what to say."

What did Frank learn at school that day? If asked, the aide might have said that he did 10 addition problems and so learned about adding. What would Frank say? One thing that is certain is that he would be very unlikely to speak to his teacher about his newly found trick for turning tongue and teeth into an abacus.

Despite his learning disability, he had long before learned not to talk too much about what was really happening in his head. He has already encountered too many teachers who demanded not only that he get the right answer, but also that he get it in the way they have decreed. Learning to let them think that he was doing it their way was part of belonging to the culture of school.

Frank's might be an extreme case, but most people share a similar fear of being made vulnerable by exposing themselves as having an inferior or messy mind. From this fear grows a habit that almost has the force of a taboo against talking freely about how we think and most especially about how we learn. If so, my joke with Frank fits very well with Freud's theory that jokes are funny precisely because they are not—they express repressed feelings that are not funny at all, in this case an undertone of something wrong with school's way of talking (and especially its way of not talking) about learning. Freud was thinking of jokes relieving tensions that come from hiding aggression and living with taboos on sexual instincts. I believe there is a similar situation in relation to learning.

This mathetic taboo has much in common with the taboos that existed until recently against talking about sexual matters. In Victorian days, or even when I was a child, sexual fantasies fell under the concept of "dirty thoughts," and although it was acceptable to recognize that other people had them, respectable people did not speak aloud about their own. It is relevant here to speculate about what lay behind this reluctance to talk. Imagine that you are a Victorian. Now, while you might be pretty sure that you are not the only one who has dirty thoughts, you would not know just how common it is, or whether people would assume you do. So better keep your mouth shut.

Whether or not this is an accurate account of Victorian sex taboos, I am sure that something analogous happens nowadays. Today, few people worry about letting on that their minds are full of sexual thoughts; many even feel a taboo against *not* talking in public about this topic. Contemporary taboos bear on different aspects of the mind. The most relevant here of many such restraints on intimacy shows itself as a widespread reluctance to allow others to see how much confusion pervades our thinking.

We do not like to appear "ignorant" or "stupid" or just plain wrong. Of course, we all know that our own minds are full of messy confusion, and that many others are in the same plight, but we imagine that some minds are tidy and neat and sharp. We see no reason to advertise not being in this class, especially in the presence of people such as bosses and teachers who have power over us. So voices within caution us to be careful of what we say: Talking too much might reveal what kind of mind we have and make us vulnerable. Eventually this caution becomes a habit.

The analogy with sexual taboos may seem to exaggerate our reluctance to talk freely about personal learning. I doubt it. My own struggle to achieve what degree of liberation I have in this respect has given me a sense of a very strong

taboo. Even now, although I have a relatively good base of intellectual security, I often catch myself in the act of covering over the confusion in my mind. I cannot seem to help wanting to give certain people an impression of greater clarity than I have and, indeed, than I think anyone really has. I have developed—and I cannot believe that I am alone in this—a whole battery of defense mechanisms, as will shortly be seen.

Exaggerated or not, the suggestion of a taboo is intended to state emphatically that getting people to talk about learning is not simply a matter of providing the subject matter and the language. The lack of language is important. But there is also an active resistance of some kind. Thus, advancing toward the goal of mathetics requires more than technical aids to discussion. It also requires developing a system of psychological support.

The simplest form of support system I can imagine is to adopt the practice of opening oneself by freely talking about learning experiences. The rest of this chapter presents an example by describing how I myself emerged from what I believe it is appropriate to call a learning disability, which afflicted me for nearly twice as long as Peck's sense of himself as a mechanical idiot.

A child at school who fails to read or do arithmetic at the appropriate age is likely to be diagnosed as suffering from a learning disability and placed in special classes. I was able to read and add at the usual age, but there were other areas where my learning fell far behind what some other children did at my age. Peck reports that he discovered when he was 37 that he could, after all, deal with mechanical problems. It took me a longer time to recover from a learning disability that had plagued me as long as I can remember: I could not remember the names of flowers. Admittedly, my agnosia in this domain was not complete. For as long as I can remember I could correctly apply the words *rose*, *tulip*, and *daffodil* to the common varieties of these plants. But I cannot really say that I knew what a rose was. I was repeatedly in embarrassing situations; when I admired roses in a garden, they would turn out to be camellias or even tulips. I certainly did not recognize wild species as roses. The names *chrysanthemum*, *dahlia*, *marigold*, and *carnation* formed a blurry cloud in my mind. The extent of my not knowing is illustrated by an incident that happened when I was well into the transition to "flower literacy."

A pot of plants with rather showy blooms appeared in a common space in the building where I have my office. At the time I was beginning to pay attention to flowers and was delighted by what appeared to me to be a very exotic specimen. When I tried to remember whether I had seen one before, the only thought that came to mind was that it was not a morning glory (a species I had "discovered" in the previous weeks). As often happens to people with learning disabilities, a strong feeling of discomfort inhibited me from simply asking the name of the plant. Instead, I tried to strike up conversations about the plant's beauty, hoping that someone would mention the name in passing.

By the time I had failed four or five times, I was engrossed in the game of finding the name without actually asking. At this point I stopped to think, and

came up with a better ploy than undirected conversation. Addressing someone who struck me as the kind of person who would know about flowers, I said, "Isn't that an unusual variety?" and success came in the form of "Oh, I don't really know one variety of petunia from another." Petunia! In the next few weeks I noticed petunias 20 times before I stopped counting. I don't imagine that some person or destiny was planting them in my path. In summer in New England, petunias are everywhere. The real puzzle is how I could have been blind to them all those years. How was it possible that so many people around me had always known what a petunia looked like while I did not? What was wrong with me?

I do not think anything is "wrong with me," but even with all the intellectual security I have been able to build on the basis of academic successes, I am still vulnerable to doubts about myself. The pain occasioned by my doubts makes me wonder about the feelings of children who find it so much more difficult than their comrades to learn to read or to add. Although the consequences of my disability were so much milder than theirs that any comparison risks being condescending, I do think there are enough common elements to make the comparison valuable. At the very least, my failure to benefit from schoolish remedies gives reason to think more carefully about standard approaches to "special education."

In school's discourse, the idea of motivation plays a primary role. "If kids won't learn they must be unmotivated, so let's motivate them." The advice certainly has no direct application to my case, for in every simple sense of the word I was already highly motivated. I often made resolutions to conquer my flower disability, and these would lead to a spurt of intense flower name-learning activity. For the same reason, laziness is no explanation either. We have to look more deeply for much more subtle and textured notions for thinking about these disabilities and strategies to overcome them. For example, in the place of the one-dimensional concept of "being motivated," I shall develop a concept of relationship with areas of knowledge having all the complexity and nuance of relationships with people.

I find it significant that despite all my fancy ideas about learning, I would fall back on schoolish modes of learning flower names. Looking for a teacher, I'd go into a flower shop and ask, "What are those? And those? And those?" Looking for a textbook, I bought a book from which I tried to associate photographs of flowers with their names. I even went on field trips to the botanical gardens where I would peer at the name tags of all the flowers. But to no avail. The frontal attack by rote learning did not work any better for me than the same schoolish methods do for children who have trouble learning school's subjects. It was like learning for a school test. I would remember the names of a few flowers for a while, but they would soon sink back into the familiar confusion. After a while the paroxysm of flower learning would pass, and I would resign myself for another year or two to being someone who "isn't good at" flower names.

One day a break came serendipitously. I was in the country in the late spring

among people who were talking about how wonderful the lupines were doing. Feeling excluded and not wanting to admit in that particular company that I had no idea what a lupine was, I used the trick that later served me well in the petunia situation. I said, "Isn't *Loo Pin* a strange name? I wonder what its origin could possibly be?" (Getting a conversation going is a good ploy used cunningly by many "learning-disabled" children.) Someone speculated intelligently: "Sounds like Wolf—lupus the wolf. But I don't see the connection." After a few rounds of comment in scattered directions (which would have died out if I had not kept stoking the conversational fire), someone said, "It looks like a wolf's tail." Someone grumbled that it didn't really. That was a relative judgment, for what mattered to me was that of all the plants in sight, only one could possibly be perceived as being in the slightest like a wolf's tail. So I concluded, correctly, that those colorful masses of what I have since learned to describe as "tall spikes" were lupines.

The aspect of the serendipity that played a key role in my development was not discovering what those flowers were called; it wasn't making a connection between a flower and a name. It was making a connection between two areas of knowledge: flower names and a particular kind of interest I happen to have in etymology. Previous experience leads me to expect that I would soon have forgotten the name *lupine*, but this time I was so delighted at my cleverness and intrigued by the etymological puzzle that the incident was still buzzing in my head when I got back to my books and could explore the word. I read that *lupine* does indeed derive from the Latin word for "wolf," but not because of the tail-like appearance of its spike. The word is traced to a belief that lupines were bad for the soil because they "wolfed" all the nutrients. Enjoyment of the wolf-theory's ambiguous status between true and false led me to pursue the research and run into a twist in the story that made it still more evocative for me.

As long as I can remember, I have been excited by paradoxical aspects of words, so my level of excitement rose when I found a paradoxical slant to the etymology of *lupine*. One no longer thinks of the lupine as wolfing nutrients. On the contrary, the lupine, as a member of the pea family, is able to capture nitrogen from the atmosphere and add value to the soil. Seeing lupines in poor soil is cause for praise rather than blame. But the name has outlived the theory on which it was based, and so became one of many examples of old ideas that are preserved in our language and maintain connections of which we are only marginally aware. My relationship with flower names was taking on a new tone as they made contact with areas I found personally interesting.

This twist also touched on another personally evocative issue. One reason for my fondness for etymology is that it provides good examples for a vendetta against the idea of any single explanation for mental phenomena. They are *all* multiply determined—and this is the essence of the way the mind works. Now the origins of flower names began to show promise as an area in which I could find strong but very simple support for this way of thinking. At first blush

etymology may seem to run counter to my preference for multiple explanations, because it so often seems to pinpoint a single historical source for a word. But finding a source is not a psychological or cultural explanation for the way the word is used. The wolfing-of-goodness theory may be at the root of a full explanation for old popular forms that seem to have been followed by Linnaeus when he called this genus of plants *Lupinus*, but it scarcely begins to be an explanation of why the name has stuck in our culture. Explaining why botanists call a plant what they do does not explain why plain folk do so—in most cases the popular language scorns the botanical name and develops its own. We say *lilac* rather than *syringa* and wear a *carnation* rather than a *dianthus* in a buttonhole. It seems plausible that a folk etymology such as the looks-like-a-wolf's-tail theory could have contributed together with the wolfing-the-goodness theory to making the name *lupine* stick in popular usage. After all, if the association occurred to one person, it is reasonable to assume that it occurred to others, and that it hovers near the threshold of consciousness of many more.

My mathetic theory does not depend on the truth of my amateur etymologizing. What matters here is that it was connected with regions of knowledge that were strongly evocative for me. The real moral of the story is how a certain engaging quality spread from words to flowers, and later from flowers to other mental domains. If I had to sum it up in a single metaphor, I would say it is about how "cold" mental regions were heated up through contact with "hot" regions.

One contact was not enough to heat up the previously chilly region of flower names. By now, as I write 2 years after the lupine incident, there has been dramatic change in my memory for flower names. It is as if they now find a place to stick. But this did not happen all at once, and by the time it did, much more than the ability to remember their names had changed in my relationship with plants.

For most of a year there was not much change, although I did not forget the word *lupine*, and I did notice myself paying attention to oddities in flower names. For example, I caught myself playing with the minor contradictions suggested by an etymologically literal-minded hearing of "white lilac" or "yellow rose." *Lilac* derives from a Persian word for the color lilac, and rosy cheeks never suggest jaundice or pallor. One can tune one's ear to sense the same kind of oddness in hearing that water lilies and arum lilies are not (in a botanical sense) lilies at all. Sometimes I felt impatient with myself for paying attention to such trivial thoughts, but they kept making small ripples in my mind, and in retrospect I am glad, because these ripples put me in a state of readiness for the grand whammer. One night (reading at about 2:00 in the morning) I ran headlong into the fact that for a botanist, a daisy is not a flower. I cannot tell whether I was more shocked at this being so or at my having lived so long without knowing it. A daisy not a flower? Come on! It's the prototypical flower—if you had asked me last year to draw a flower, I'm sure I'd have produced something more like a daisy than like anything else. Though it seems silly now, and rather ignorant, I really was upset

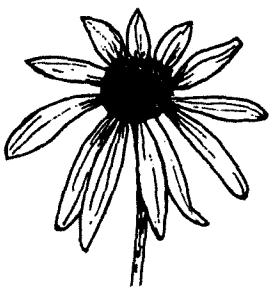

FIG. 1.1 The family of flowers that includes daisies, asters, sunflowers, and coneflowers are called inflorescences because what we usually call a flower is seen by the botanist as a mass of tiny flowers.

and excited. I ran from book to book in the small hours, trying to learn more. The news was bad: The putsch against standard nomenclature went beyond daisies to include sunflowers and black-eyed susans and chrysanthemums and dahlias. They were denigrated with names like "false flower" or elevated with fancy names like "inflorescence," but it appeared that in many circles it is a definite gaffe to call them flowers. How can this be? A sunflower isn't a flower? Even arum lilies, which had already been slighted in my mind by not being lilies, were now excluded from being flowers. (See Fig. 1.1.)

The most powerful moment came in the morning when I could at last get hold of some flowers. I found myself in a situation that would be repeated several times in the following year: I was looking at a familiar object with a sense of looking at it for the first time. Compare a buttercup with a daisy and you may begin to understand how the botanist sees them as fundamentally different things. For the botanist a flower is structured around its sex organs: The stamens and anthers, the pistils, stigmas, and ovaries are the essence of the flower. The petals and sepals that make such a spectacularly colorful impression on us and on the birds and insects are secondary features. In the buttercup, the tulip, and the lily you can see all these parts—but not in the daisy. Or rather, in the daisy you see the parts repeated many times, for those white slivers you may have pulled off one by one while reciting "loves me . . . loves me not . . ." are not petals surrounding sex organs but entire flowers. If you pull one out very carefully, you will see that it is like a miniature, lopsided, and elongated petunia. And what they surround, the central yellow disk, is itself a mass of even tinier complete flowers. So botanically speaking, the daisy is not a flower but a tight bunch of flowers of two kinds, ray flowers on the outside surrounding disk flowers on the inside. The botanist will call it a head or an inflorescence, though I suppose and hope that children will always call it a flower.

Up to this point my new involvement with flowers was confined to their names and belonged squarely in my established area of hot interest in etymology. With the daisy incident it broke out from words to things. I began to look at flowers and think about their structure. The concept of flower was changing, and new conceptual entities began to grow in my mind: The unit of thought shifted from the flower to the whole plant, and, by degrees, previously nebulous entities

FIG. 1.2. The disk or mass at the center of many inflorescences is made up of many tiny flowers like this one. What seem to be petals are also complete flowers in themselves.

such as "the rose family" (which includes cherries, apples, and strawberries as well as roses) acquired firmer reality. I also began to think about botanists. It was easy to see that their definition of flower excluded daisies; this was a simple matter of logic. But coming to appreciate the reasons for adopting such a definition was an essentially different and more complex process, better characterized as entering a culture than as understanding a concept. (See Fig. 1.2.)

Naming remained an important theme in an increasingly complex set of relationships in my mind. A simple example started with the name of the daisy. Now that the humble flower had become such a center of interest, I naturally poked around the origins and meanings of its name. I could hardly believe my luck: *Daisy* is "day's eye"! What a find, accompanied again by my amazement at not having known this and even some shamefaced puzzling about why it had not been obvious. The find got extra spice from the fact that different books gave different explanations. One theory had the daisy looking like the sun, which is the "eye of the day"; another associated it with the tendency of daisies to open in the day and close at night. Another started with a speculation. I had run into the fact that daisies were thought to have good medicinal properties for afflictions of the eye. A first guess that this might be related to its name seemed to me too implausible to be worth checking. Doing so, all the same, led to another curious find: the doctrine of signatures, which held that plants show by their visible properties their medicinal virtues. The self-heal, a wildflower, shows its value for treating throat ailments by the fact that its flower has a throat, and this is reflected in the derivation of its botanical name, *Prunella vulgaris*, from "Breune," the German word for "quinsy" (an old-fashioned name, as I learned through the same investigation, for tonsillitis). The coloration patterns of hepatica leaves are said to suggest the appearance of the liver, thus explaining both the name *hepatica*—from the Latin word meaning "having to do with the liver"—and the belief that it is good for liver ailments. Certain features of plants became more salient, for example, that some have throats and some do not. The interest in names was bringing me into the real world of flowers.

Other connections with names and naming led into new relationships with nature. The window of the room where most of this book was written looks out on a field where I see wildflowers of several colors, particularly yellows and purples. Among the yellows I can see tall, bushy Saint-John's-worts and even

taller evening primroses, little cinquefoils, and some early goldenrod. Among the purples I see fireweed, loosestrife, and asters. I also see some that are question marks in my head: I have noted their existence but do not know what they are. Two years ago I saw an undifferentiated display of pretty flowers. It was beautiful. I loved it. But it was not at all what I am seeing now. Try as I might, I cannot make my eye go back to seeing it as I did before. I cannot imagine what it would be like to see those yellow flowers as a mass of yellow flowers without individual identity.

I want to pursue a detail in this development as a model for the process of learning. Two years ago I knew the name *buttercup* and correctly applied it to common buttercups. I cannot recall how widely I would have used this name to apply to other species, but I am sure that I had no other words for small yellow flowers. Early in the first summer I became aware of two other kinds of yellow wildflowers: cinquefoils and Saint-John's-worts. But my degree of flower dyslexia showed itself in the fact that I had to reidentify these flowers many times—like someone who cannot hold a tune, I could not hold the distinction from one day to the next. All the same, something had happened: It was as if I had made pegs in my head for three things—buttercups, cinquefoils, and Saint-John's-worts—but did not yet know what to hang on each peg, or that I had met three people and had been told their names, but knew nothing else about them. I often find myself in this situation and am struck by how I get new entities mixed up until a gradually growing sense of individuality becomes strong enough to keep them separate. The sense of individuality grew slowly and unevenly for the three kinds of plant.

I do not pretend to know exactly how this process of growth happened. But I do know how it did *not* happen: I tried to memorize the characteristics of each group taken from a book, but this simply did not work. Perhaps if I had been interested only in these three flowers, I would have been able to memorize their formal characterizations. But if I turned to other plants and came back to the three yellow ones, I would get them wrong again. Slowly something different from the rote memory of botanists' defining characteristics developed; I began to build up a more personal kind of connection.

I associate buttercups with folklore that tells about the appearance of a person's chin when a buttercup is held up to it. If the chin takes on the yellow color by reflection, this is interpreted in America as a sign of liking butter and in France, naturally, as a sign of being in love. Through these stories I associate the buttercup with shiny petals, one of the characteristics that in fact distinguishes it from the other two. Other associations were less direct. One of the three flowers has especially bushy stamens. I could not remember which. In fact, it is the Saint-John's-wort, but when I read that this plant is also known as Aaron's beard, I associated this name with its bushy stamens because these are like a beard, and with the name Saint-John's-wort because Aaron and St. John both have a biblical connection. So the name Aaron's beard acted as a kind of glue to stick the bushy

stamen property to the name *Saint-John's-wort.* During the same period I found my visual attention shifting from the flower to the plant, and this brought new kinds of association. And so it went.

The deeper I got into my "affair" with flowers, the more connections were made; and more connections meant that I was drawn in all the more strongly, that the new connections supported one another more effectively, and that they were more and more likely to be long-lasting. Moreover, the content of my learning spread in many directions: I was learning Latin words, I was picking up insights into the history of folk-medicine, and I was gaining or renewing geographic and historical knowledge. The Renaissance in its artistic and scientific aspects came into new focus through the role of flowers in the new relationship with nature that developed at that time.

My learning had hit a critical level in the sense of the "critical mass" phenomenon of a nuclear reaction or the explosion of a population when conditions favor both birthrate and survival. The simple moral is that learning explodes when you stay with it: A full year had passed before the effect in my mind reached a critical level for an exponential explosion of growth. The more complex moral is that some domains of knowledge, such as plants, are especially rich in connections and particularly prone to give rise to explosions of learning.

My learning experience with flowers began with a very narrow "curriculum": learning to name them. In the end the experience widened and left me a different person in more dimensions of life than anything that is measured by the standardized behavioristic tests with which the conservatives judge school learning. It affected my stream of consciousness as I moved about the world: I see more as I walk in the street or in a field. The world is more beautiful. My sense of oneness with nature is stronger. My caring about environmental issues is deep and more personal. And recently I have surprised myself by enjoying systematic books on botany and having no trouble remembering what I read. It is as if I have made my transition in this domain from a concrete to a formal stage.

Early in this chapter I mentioned a mathetic weakness in the literature on constructivism. The metaphor of learning by constructing one's own knowledge has great rhetorical power against the image of knowledge transmitted though a pipeline from teacher to student. But it is only a metaphor, and reflection on my flower story consolidates my sense that other images are just as useful for understanding learning, and are more useful as sources of practical mathetic guidance. One of these is *cultivation:* Developing my knowledge of plants felt more like the work of a horticulturalist designing, planting, and tending a garden than the work of a construction crew putting up a house. I have no doubt that my knowledge developed even when I was not paying attention! Another image is the geographic metaphor of regions and the idea of connections between them. Indeed, the description "connectionism" fits my story better than "constructivism."

On a pragmatic level, "Look for connections!" is sound mathetic advice, and

on a theoretical level, the metaphor leads to a range of interesting questions about the connectivity of knowledge. It even suggests that the deliberate part of learning consists of making connections between mental entities that already exist; new mental entities seem to come into existence in more subtle ways that escape conscious control. However that may be, thinking about the interconnectivity of knowledge suggests a theory of why some knowledge is so easily acquired without deliberate teaching. In the sense in which it is said that no two Americans are separated by more than five handshakes, this cultural knowledge is so interconnected that learning will spread by free migration to all its regions. This suggests a strategy to facilitate learning by improving the connectivity in the learning environment by actions on cultures rather than on individuals.

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