

Situating Constructionism

By Seymour Papert and Idit Harel

The following essay is the first chapter in Seymour Papert and Idit Harel's book *Constructionism* (Ablex Publishing Corporation, 1991).

It is easy enough to formulate simple catchy versions of the idea of constructionism; for example, thinking of it as "learning-by-making." One purpose of this introductory chapter is to orient the reader toward using the diversity in the volume to elaborate--to construct--a sense of constructionism much richer and more multifaceted, and very much deeper in its implications, than could be conveyed by any such formula.

My little play on the words construct and constructionism already hints at two of these multiple facets--one seemingly "serious" and one seemingly "playful." The serious facet will be familiar to psychologists as a tenet of the kindred, but less specific, family of psychological theories that call themselves constructivist. Constructionism--the N word as opposed to the V word--shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. And this in turn implies a ramified research program which is the real subject of this introduction and of the volume itself. But in saying all this I must be careful not to transgress the basic tenet shared by the V and the N forms: If one eschews pipeline models of transmitting knowledge in talking among ourselves as well as in theorizing about classrooms, then one must expect that I will not be able to tell you my idea of constructionism. Doing so is bound to trivialize it. Instead, I must confine myself to engage you in experiences (including verbal ones) liable to encourage your own personal construction of something in some sense like it. Only in this way will there be something rich enough in your mind to be worth talking about. But if I am being really serious about this, I have to ask (and this will quickly lead us into really deep psychological and epistemological waters) what reasons I have to suppose that you will be willing to do this and that if you did construct your own constructionism that it would have any resemblance to mine?

I find an interesting toe-hold for the problem in which I called the playful facet--the element of tease inherent in the idea that it would be particularly oxymoronic to convey the idea of constructionism through a definition since, after all, constructionism boils down to demanding that everything be understood by being constructed. The joke is relevant to the problem, for the more we share the less improbable it is that our self-constructed constructions should converge. And I have learned to take as a sign of relevantly common intellectual culture and preferences the penchant for playing with self-referentially recursive situations: the snake eating its tail, the man hoisting himself by his own bootstraps, and the liar contradicting himself by saying he's a liar. Experience shows that people who relate to that kind of thing often play in similar ways. And in some domains those who play alike think alike. Those who like to play with images of structures emerging from their own chaos, lifting themselves by their own bootstraps, are very likely predisposed to constructionism.

They are not the only ones who are so predisposed. In Chapter 9 of this volume, Sherry Turkel and I analyze the epistemological underpinnings of a number of contemporary cultural movements. We show how trends as different as feminist thought and the ethnography of science join with trends in the computer culture to favor forms of knowledge based on working with concrete materials rather than abstract propositions, and this too predisposes them to prefer learning in a constructionist rather than in an instructionist mode. In Chapter 2, I make a similar connection with political trends.

It does not follow from this that you and I would be precluded from constructing an understanding about constructionism in case you happened not to be in any of the "predisposed groups" I have mentioned. Of course not. I am not prepared to be "reductionist" quite to that extent about arguing my own theory, and in the following pages I shall probe several other routes to get into resonance on these issues: for example, stories about children are evocative for more people than recursions and can lead to similar intellectual positions.(1) But there is no guarantee; I have no argument like what is supposed to happen in formal logic where each step leads a depersonalized mind inexorably along a pre-set path. More like the tinkerer, the *bricoleur*, we can come to agreement about theories of learning (at least for the present and perhaps in principle) only by groping in our disorderly bags of tricks and tools for the wherewithal to build understandings. In some cases there may be no way to do it one-on-one but a mutual understanding could still be socially mediated: for example (to recall the context of discussing how to use this volume) we might both find ourselves in tune with Carol Strohecker and her evocative descriptions of working with knots. (2) Through her we might come together. But what if we didn't find a route to any understanding at all? This would be tragic if we were locked into a classroom (or other power ridden) situation where one of us has to grade the other; but in the best phases of life, including real science and mathematics, it turns out much more often than is admitted in schools to be right to say: *vivent les differences!*

I might appear in the previous paragraph to be talking about accepting or rejecting constructionism as a matter of "taste and preference" rather than a matter of "scientific truth." But a distinction needs to be made. When one looks at how people think and learn one sees clear differences. Although it is conceivable that science may one day show that there is a "best way," no such conclusion seems to be on the horizon. Moreover, even if there were, individuals might prefer to think in their own way rather than in the "best way." Now one can make two kinds of scientific claim for constructionism. The weak claim is that it suits some people better than other modes of learning currently being used. The strong claim is that it is better for everyone than the prevalent "instructionist" modes practiced in schools. A variant of the strong claim is that this is the only framework that has been proposed that allows the full range of intellectual styles and preferences to each find a point of equilibrium.

But these are not the questions to guide research in the next few years for they presuppose that the concept of constructionism has reached a certain level of maturity and stability. The slogan *vivent les differences* might become inappropriate at that stage. But when the concept itself is in evolution it is appropriate to keep intellectual doors open and this is where we are now. To give a sense of the methodology of this early "pre-paradigmatic" stage I shall tell some stories about incidents that fed the early evolution of the idea.

More than 20 years ago, I was working on a project at the Muzzey Junior High School in Lexington, MA, which had been persuaded by Wally Feuerzeig to allow a seventh grade to "do Logo" instead of math for that year. This was a brave decision for a principal who could not have known that the students would actually advance their math achievement score, even though they didn't do anything that resembled normal school math that year! But the story I really want to tell is not about test scores. It is not even about the math/Logo class. (3) It is about the art room I used to pass on the way. For a while, I dropped in periodically to watch students working on soap sculptures and mused about ways in which this was not like a math class. In the math class students are generally given little problems which they solve or don't solve pretty well on the fly. In this particular art class they were all carving soap, but what each students carved came from wherever fancy is bred and the project was not done and dropped but continued for many weeks. It allowed time to think, to dream, to gaze, to get a new idea and try it and drop it or persist, time to talk, to see other people's work and their reaction to yours--not unlike mathematics as it is for the mathematician, but quite unlike math as it is in junior high school. I remember craving some of the students' work and learning that their art teacher and their families had first choice. I was struck by an incongruous image of the teacher in a regular math class pining to own the products of his students' work! An ambition was born: I want junior high school math class to be like that. I didn't know exactly what "that" meant but I knew I wanted it. I didn't even know what to call the idea. For a long time it existed in my head as "soap-

sculpture math."

Soap-sculpture math is an idea that buzzes in the air around my head wherever I go (and I assume it was present in the air the students who wrote the chapters in this volume breathed). Has it been achieved? Of course not. But little by little by little we are getting there. As you read the chapters you will find many examples of children's work that exhibits one or another of features of the soap-sculpting class. Here I mention two simple cases which happened to move me especially deeply.

Last year, at Project Headlight of the Hennigan School in Boston, MA, I watched a group of children trying to make a snake out of LEGO/Logo. They were using this high-tech and actively computational material as an expressive medium; the content came from their imaginations as freely as what the others expressed in soap. But where a knife was used to shape the soap, mathematics was used here to shape the behavior of the snake and physics to figure out its structure. Fantasy and science and math were coming together, uneasily still, but pointing a way. LEGO/Logo is limited as a build-an-animal-kit; versions under development in our lab will have little computers to put inside the snake and perhaps linear activators which will be more like muscles in their mode of action. Some members of our group have other ideas: Rather than using a tiny computer, using even tinier logic gates and motors with gears may be fine. Well, we have to explore these routes (4). But what is important is the vision being pursued and the questions being asked. Which approach best melds science and fantasy? Which favors dreams and visions and sets off trains of good scientific and mathematical ideas?

Last week, I watched a tape of children from Project Mindstorm at the Gardner Academy in San Jose, CA. A fifth grader who was in his second year of working with LogoWriter was showing a spectacular sample of screen graphics he had programmed. When asked how he did it, he explained that he had to figure angles and curvatures to obtain the greatest "grace." His product was no less desirable than the soap sculptures, and its process much more mathematical than anything done in a usual math classroom. And he knew it, for he added with pride: *I want to be a person who puts math and art together.* Here again I hear answers to questions about taking down walls that too often separate imagination from mathematics. This boy was appropriating mathematics in a deeply personal way. What can we do to encourage this?

I'll tell another story to introduce a second idea. At the time of the Muzzey project in Lexington, Logo had not yet acquired the feature for which it is best known to most educators: It had no graphics, no Turtle. In fact, at Muzzey School there was no screen, only clanging teletype terminals connected to a distant "time-shared" computer. (In fact, the origination of the Logo Turtle was inspired by the soap-sculpture image and a few others like it.) About 10 years later, I was working with Sherry Turkle (5) and John Berlow at the Lamplighter School in Dallas, TX, the first elementary school where there were enough computers for children to have almost free access to them. The first space shuttle was about to go up, and in the tension of waiting for it appeared in many representations on screens all over the school. "Even the girls are making space ships," one girl told us. But we noticed that although everyone had space ships they did not make them the same way. Some programmed their space ships as if they had read a book on "structured programming," in the top-down style of work that proceeds through careful planning to organize the work and by making subprocedures for every part under the hierarchical control of a superprocedure. Others seemed to work more like a painter than like this classical model of an engineer's way of doing things. The painter-programmer would put a red blob on the screen and call over her friends (for it was more often, though not always, a girl) to admire the shuttle. After a while someone might say: "But its red, the shuttle is white." "Well, that's the fire!"--came the reply--"Now I'll make the white body." And so the shuttle would grow, taking shape through a kind of negotiation between the programmer and the work in progress.

This and many other such incidents initiated an intense interest in differences in ways of doing things, and during the next few years (6) (which means into the time when the work in this volume

was starting), "style" was almost as much in the air as the "soap-sculpture." I was very much troubled by questions about whether styles were categorical or a continuum, whether they were correlated with gender or ethnic cultures or personality types. These two key ideas set the stage for the evolution of constructionism.

Constructionism's line of direct descent from the soap-sculpture model is clearly visible. The simplest definition of constructionism evokes the idea of learning-by-making and this is what was taking place when the students worked on their soap sculptures. But there is also a line of descent from the style idea. The metaphor of a painter I used in describing one of the styles of programmer observed at the Lamplighter school is developed in Chapter 9 by Turkle and Papert in two perspectives. One ("bricolage") takes its starting point in strategies for the organization of work: The painter-programmer is guided by the work as it proceeds rather than staying with a pre-established plan. The other takes off from a more subtle idea which we call "closeness to objects"--that is, some people prefer ways of thinking that keep them close to physical things, while others use abstract and formal means to distance themselves from concrete material. Both of these aspects of style are very relevant to the idea of constructionism. The example of children building a snake suggests ways of working in which those who like bricolage and staying close to the object can do as well as those who prefer a more analytic formal style.

Building and playing with castles of sand, families of dolls, houses of Lego, and collections of cards provide images of activities which are well rooted in contemporary cultures and which plausibly enter into learning processes that go beyond specific narrow skills. I do not believe that anyone fully understands what gives these activities their quality of "learning-richness." But this does not prevent one from taking them as models in benefiting from the presence of new technologies to expand the scope of activities with that quality.

The chapters in this book offer many constructions of new learning-rich activities with an attempt to reach that quality. A conceptually simple case is the addition of new elements to LEGO construction kits and to the Logo microworlds, so that children can build more "active" models. For example, sensors, miniaturized computers that can run Logo programs, and motor controllers allow a child (in principle) to build a LEGO house with a programmable temperature control system; or to construct forms of artificial life and mobile models capable of seeking environmental conditions such as light or heat or of following or avoiding one another. Experiments carried out so far still fall a little short of this idealized description, and, moreover, have been mounted systematically only in the artificial contexts of schools or science centers. But it is perfectly plausible that further refinement of the components (combined, be it noted for further discussion below, with suitable marketing) might result in such "cybernetic" activities (as we choose to call them), thus becoming as much part of the lives of young children as playing with toys and dolls, or other more passive construction kits. It is also plausible that *if* this were to happen, certain concepts and ways of thinking presently regarded as far beyond children's ken would enter into what they know "spontaneously" (in the sense in which Piaget talks about children's spontaneous geometry or logic or whatever), while other concepts--which children do learn at school but reluctantly and not very well--would be learned with the gusto one sees in Nintendo games.

This vision advances the definition of constructionism and serves as an ideal case against which results that have been actually achieved can be judged. In particular, it illustrates the sense of the opposition I like to formulate as *constructionism vs. instructionism* when discussing directions for innovation and enhancement in education.

I do not mean to imply that construction kits see instruction as bad. That would be silly. The question at issue is on a different level: I am asking what kinds of innovation are liable to produce radical change in how children learn. Take mathematics as an extreme example. It seems obvious that as a society we are mathematical underperformers. It is also obvious that instruction in mathematics is on the average very poor. But it does not follow that the route to better performance is necessarily the

invention by researchers of more powerful and effective means of instruction (with or without computers).

The diffusion of cybernetic construction kits into the lives of children could in principle change the context of the learning of mathematics. Children might come to *want* to learn it because they would use it in building these models. And if they did want to learn it they would, even if teaching were poor or possibly nonexistent. Moreover, since one of the reasons for poor teaching is that teachers do not enjoy teaching reluctant children, it is not implausible that teaching would become better as well as becoming less necessary. So changes in the opportunities for construction could in principle lead to deeper changes in the learning of mathematics than changes in knowledge about instruction or any amount of "teacher-proof" computer-aided instruction.

This vision is presented as a thought experiment to break the sense of necessary connection between improving learning and improving teaching. But many of its elements can be related to real experiments described in the book. The potentially engaging qualities of the cybernetic construction kit is well established through work on the simpler version of it known as LEGO/Logo. The direct spill-over of LEGO/Logo onto mathematical learning is not discussed in this book, but a spill-over of something else in the same spirit was created and documented by Idit Harel for her doctoral dissertation (7). Her experiments show that children's attention can be held for an hour a day over periods of several months by making (as opposed to using) educational software—even when the children consider the content of the software to be utterly boring in its usual classroom form. Moreover, here we do see statistically hard evidence that constructionist activity—which integrates math with art and design and where the children make the software—enhances the effectiveness of instruction given by a teacher in the same topic (in the case in point, fractions).

Although most of the examples in the book use computers, some do not. Most strikingly, a "knot lab" has children building such unorthodox entities as a family tree of knots. Why is it included in this volume? Its designer, Carol Strohecker, would say "why knot?" (8) Constructionism and this book are about learning; computers figure so prominently only because they provide an especially wide range of excellent contexts for constructionist learning. But common old garden string, though less versatile in its range, provides some as well. The point is that the Knot Lab, the Software Design Studio, LEGO/Logo workshops, and other learning environments described in this book all work in one way; while instructionist learning environments, whether they use CAI or the pencil-and-paper technology of traditional classrooms, work in a different way.

The assertion that the various constructionist learning situations described here "work in one way" does not mean they are not very different. Indeed, in form they are very different, and intellectual work is needed to see what they have in common. The construction of physical cybernetic creatures is made possible by novel hardware. In a closely related example, Mitchel Resnick opened a new range of activities by creating a new software system: an extension of Logo called *Logo which enables a child to create thousands of "screen creatures" which can be given behaviors to produce phenomena similar to those seen in social insects (9). Judy Sachter created a software system for children to work in 3-D graphics (10). Idit Harel used existing hardware and software; her invention (like Carol Strohecker's) was on a social level. She organized children into a Software Design Studio within which they learned by teaching, which gave cultural, pedagogical, as well as technical support for the children to become software designers.

There cannot be many research groups in education with the capability of innovating in so many ways. (Is this one result of constructionist environments?) Still, what makes the Epistemology and Learning Group unique is not this diversity as such, but the search for underlying unity. The creation of a multitude of learning situations (sometimes called learning environments or microworlds) is a great asset, but what gives constructionism the status of a theoretical project is its epistemological dimension.

Instructionism vs. constructionism looks like a split about strategies for education: two ways of thinking about the transmission of knowledge. But behind this there is a split that goes beyond the acquisition of knowledge to touch on the *nature of knowledge* and the *nature of knowing*. There is a huge difference in status between these two splits. The first is, in itself, a technical matter that belongs in an educational school course on "methods." The second is what ought properly to be called "epistemological." It is close to fundamental issues that philosophers think of as their own. It raises issues that are relevant to the nature of science and to the deepest debates in psychology. It is tangled with central issues of radical thinking in feminism, in Africanism, and in other areas where people fight for the right not only to think what they please, but to think it in their own ways.

Concern with ways of knowing and kinds of knowledge is pervasive in all the chapters in this volume (11) and this is what creates connection with a contemporary movement that goes far beyond education. Indeed, manifestations of the movement in question do not always label themselves as directly concerned with education. And even when they do, the educational concerns they express seem at first sight to be disconnected. This is demonstrated by the complexities of some common issues that appear in different guises in my own contributions to this collection. My chapter with Sherry Turkle ("Epistemological Pluralism and the Revaluation of the Concrete," Chapter 9) distills an epistemological essence from inquiry into the sociology of knowledge. My closing speech at the World Congress on Computers and Education ("Perestroika and Epistemological Politics," Chapter 2) looks at the same epistemological categories through political metaphors (which may well be more than metaphoric). And my chapter with Idit Harel ("Software Design as a Learning Environment," Chapter 4) looks at them through the lens of a particular educational experience. The understanding that my concerns with ways of knowing and kinds of knowledge are not disconnected from educational concerns grew out of my concerns with knowledge appropriation and styles of thinking (or one's style of making a piece of knowledge one's own); it is time to pick this thread up again.

In the chapter by Turkle and Papert the question of style takes on a new guise. The issue has shifted from the psychological question--Who thinks in one style or the other?--to the epistemological question of characterizing the differences. In that chapter we take a new look at the confluence of "noncanonical" epistemological thinking from sources as diverse as the ethnographic study of laboratories, intellectual movements inspired by feminist concerns, and trends within computer cultures. It is clear enough that each of these streams taken separately carries implications for education. But to capture a common implication one has to look beyond what one might call "a first impact," which in each case tends to be specific rather than common, focused on educational content rather than on underlying epistemologies. Thus, feminism's first and most obvious influence on education was tied to issues that very specifically affect women, for example, the elimination of gender stereotypes from school books, without in any way discounting its importance (and the likelihood that the waves it creates will go much further). I call this a "cleanup" because in itself it is compatible with similar books. While this can be, and usually is, implemented as a very local change, the implications of feminist challenges to received ideas about the nature of knowing run radically deeper. For example, traditional epistemology gives a privileged position to knowledge that is abstract, impersonal, and detached from the knower and treats other forms of knowledge as inferior. But feminist scholars have argued that many women prefer working with more personal, less-detached knowledge and do so very successfully. If this is true, they should prefer the more concrete forms of knowledge favored by constructionism to the propositional forms of knowledge favored by instructionism. The theoretical thrust of "Epistemological Pluralism" is to see this epistemological challenge as meshing with those made by the other two trends it analyzes.

The need to distinguish between a first impact on education and a deeper meaning is as real in the case of computation as in the case of feminism. For example, one is looking at a clear case of first impact when "computer literacy" is conceptualized as adding new content material to a traditional curriculum. Computer-aided instruction may seem to refer to method rather than content, but what counts as a change in method depends on what one sees as the essential features of the existing

methods. From my perspective, CAI amplifies the rote and authoritarian character that many critics see as manifestations of what is most characteristic of--and most wrong with--traditional school. Computer literacy and CAI, or indeed the use of word-processors, could conceivably set up waves that will change school, but in themselves they constitute very local innovations--fairly described as placing computers in a possibly improved but essentially unchanged school. The presence of computers begins to go beyond first impact when it alters the nature of the learning process; for example, if it shifts the balance between transfer of knowledge to students (whether via book, teacher, or tutorial program is essentially irrelevant) and the production of knowledge by students. It will have really gone beyond it if computers play a part in mediating a change in the criteria that govern what *kinds of knowledge are valued* in education. The crucial thesis of "Epistemological Pluralism" is that while computers are often seen as supporting the abstract and impersonal detached kinds of knowing (which have drawn fire from feminists), computational thinking and practice has been shifting in the opposite direction towards a potential synergy with the feminist position.

Ethnographic studies of science provide a final example of a contrast between a superficial--though as in the other cases still valuable--first impact, and a potentially deep epistemological one. Work by Latour, Traweek, Keller, and many others has produced a picture of how scientists actually work that should be shared with children: But telling children how scientists do science does not necessarily lead to far-reaching change in how children do science; indeed, it cannot, as long as the school curriculum is based on verbally-expressed formal knowledge. And this, in the end, is what construction is about.

Footnotes

(1) I understand Piaget better when he lets the concrete thinker in him emerge in his playing with extracts from children's dialogue than when he writes as a "formal" thinker. This does not mean that I do not agree with the essential core of Piaget's thinking, though I am less sure that *he himself* always does.

(2) In Chapter 12 of *Constructionism*.

(3) This math/Logo class is the source of several anecdotes in my book *Mindstorms* (1980); it is also discussed in my paper *Teaching Children Thinking* (1971).

(4) For further descriptions of LEGO/Logo and LEGO Creatures learning environments, see Chapters 7, 8, 15, 188, and 19 of *Constructionism*.

(5) Sherry Turkle has written a theoretical analysis of this experience which should be read by everyone interested in children and computers: *The Second Self: The Human Spirit in the Computer Culture*. See also Chapter 9 by Turkle and Papert in *Constructionism*.

(6) Observations on differences in styles of Logo programming were reported in Papert, Watt, diSessa, & Weir (1979). Sylvia Weir, who participated very actively in the pre- and early periods of the Epistemology and Learning group developed an approach to style in her book *Cultivating Minds: A Logo Casebook* (1986).

(7) See Idit Harel's dissertation *Software Design for Learning: Children's Construction of Meaning for Fractions and Logo Programming* (1988) which was revised and published as *Children Designers: Interdisciplinary Constructions for Learning and Knowing Mathematics in a Computer-Rich School* (1991). See also Chapters 4, 5, 6, and 22 in *Constructionism*.

(8) See Carol Stroheker's dissertation (1991), and Chapter 12 in *Constructionism*.

(9) See Chapters 11 and 19 in *Constructionism*.

(10) See Chapter 17 in *Constructionism*.

(11) See especially Part III, "Thinking about Thinking: Epistemological Styles in Constructionist Learning," Chapters 9 through 17 in *Constructionism*.

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