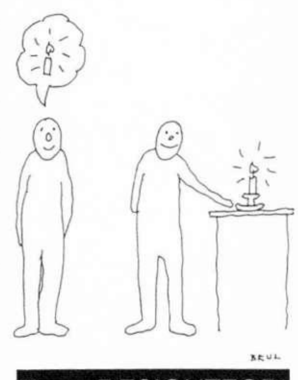
Learning to Design and Designing to Learn

by Donald A. Schön

Herbert Simon has asserted that all practitioners, because they produce artifacts of one kind or another, are designers. In the narrower sense of the term that is associated with traditional design professions, practitioners produce artifacts like buildings, bridges or industrial products. In the broader sense of design, practitioners produce artifacts like legal arguments, strategic business plans, or medical diagnoses. Simon concludes that a science of design – a science of the artificial – is the proper foundation for professional education.[1] Although I very much agree with Simon's bold surmise, I disagree with his instrumental view of designing.



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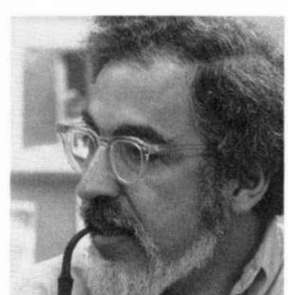
Talk delivered to the International Conference on Theories and Methods of Design, May, 1992.



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In contrast to Simon's view of designing as heuristic search within a field of constraints, I shall argue that designing is a *transaction* with the materials of a design situation.[2] Designers make things under conditions of complexity and uncertainty. If at times they engage in "searching", they also help to create the field of objects and relations within which they search. These are some of the the main features of design transactions:

• Whether designers operate on the site and or in the virtual world of a sketchpad, scale model or computer screen, they deal with *materials*.

• Through active, sensory appreciation of actual or virtual worlds designers construct and reconstruct objects and relations, determine "what is there" for purposes of design, and thereby create "*design worlds*" within which they function.[3]

• A design world may be unique to a particular designer or shared by a larger design community – to what degree unique or shared being always an open question – to be explored anew in each instance of designing. Certainly, the more innovative the designing, the more likely the design world is to be unique.

• Most designing is social. Designers occupy institutional roles and interact in their designing with one another. Hence, their activity is essentially *communicative*: the artifacts they make and the moves by which they make them are messages which must be sent, received and deciphered.

• Designing is a "*conversational*" transaction between the designer and the materials of a problematic situation.[4] A designer "sees", "moves", and "sees" again. He or she makes an initial appreciation of the situation, moves in relation to it, receives the situation's "back-talk", and moves again. At its best, the designer's conversation with the situation becomes reflective. The designer "listens" to the back-talk, reflects on its meaning and, on the basis of that reflection, restructures the understanding that informed his initial appreciations and invented moves.

Such a reflective conversation with materials is epitomized by Edmund Carpenter's description of the Inuit sculptor scraping away at a bone, looking at it now this way and now that, finally exclaiming, "Ah, Seal".[5] But a reflective conversation with the materials of a situation is also exemplified by a classroom teacher who hears the strange question her student asks ("What happened to the sun during yesterday's eclipse?", for example), puzzles over its meaning, and searches for the questions she might ask that would enable her student to reveal both the meaning of his question and the spontaneous, pre-existing knowledge on which it is based.

In the remainder of this paper, I shall explore some relationships between learning and designing when designing is seen as the kind of conversational transaction I have sketched above. I shall explore how learning enters into the process of design, and what it might mean to see teaching and learning through the lens of designing.

I shall begin with a homely example of designing that is also an example of learning and teaching.

Double Designing: Constructing Design Worlds and Structures Within Them

Designers (in the narrow sense) deal with material objects such as wooden trusses, steel girders and reinforced concrete beams. From one point of view, nothing could be more solidly real than things like these; they are just what they are. On the other hand, given a stock of available materials, different designers often select different objects, and even appreciate the "same" objects in different ways, in terms of different meanings, features, elements, relations, and groupings, all of which enter into characteristically different design worlds.

It is worth noting that the concept of design world is closely related to that of style. It is a mistake to think about style as a relatively trivial add-on to the substance of design knowledge. When we consider, for example, the style of Frank Lloyd Wright's Usonian houses, or Mies

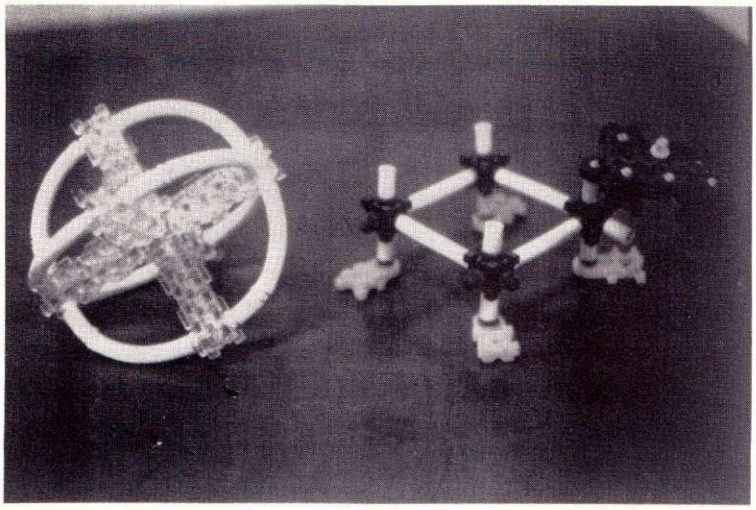


Figure 1. U-Chin's and Rex's Modula Constructions.

Van Der Rohe's office buildings, we find characteristic elements used and combined according to characteristic relationships. David Billington has shown how the design of bridges evolved in the 19th century as their designers came to see and exploit in new ways the potentials inherent in reinforced concrete.[6] John Habraken has described the styles of post-and-beam construction, Pompeian houses, and 17th century Amsterdam town houses, where in each instance a family of characteristic elements are combined according to characteristic relationships, yielding a variety of formal possibilities.[7]

The example I shall discuss here is a design game that Jeanne Bamberger and I had our students play in a course we taught called "Learning to Design and Design for Learning". In it, we gave the students three different construction systems: LEGO, Tinkertoys, and Modula, a new system that had been designed for use by engineering undergraduates. Four of our students – Mimi, U-Chin, Rex and Bob – were asked to "make something they liked" using each of the construction systems in turn. In a sense, then, these students had the same materials to work with. But because each of them saw the materials in a different way, chose to use different items, singled out different features, and exploited different relationships among items and features, each student constructed a unique design world.

For example, the Modula set contained tubes. Mimi and Bob did not use them at all. U-Chin used them as though they were rigid beams. Only Rex took advantage of their flexibility. (Figure 1.)

Each of the students put together different construction modules and connectors, out of which he or she made a larger building system. U-Chin found a blue cube and fitted it with club-shaped connectors, each plugged into a hole on one surface of the cube. He said this was "neat", replicated it, and used it to make his structure. Rex also found the cube; however, he chose to make bricks out of the Modula pieces

that were intended for that purpose and assembled them, a brick attached to each surface of the cube. (Figure 2.)

Bob also made his own version of the brick-based modules, stringing them together with long rods. (Figure 3.)

Choices of modules and connectors were associated with different interpretations of the design task. For example, Bob and Rex, both of whom made Modula bricks, had different ideas of what it meant to connect them together. Mimi used the Modula pieces more or less as they came because, she said, "I thought we were supposed to". She built her structure piece by piece *in situ*. (Figure 4.)

Bob and Rex used the hammer to make their bricks, but Mimi and U-Chin chose not to use it – Mimi, because she said it seemed like "cheating," U-Chin because he disliked the idea of making "permanent connections," and both of them because they "didn't like the noise".

The choices of modules and connectors were also linked to prestructures, or prototypes, that the students brought to the task. Mimi, for example, had made her LEGO structure before her Modula one, and had placed her Modula structure on a LEGO base. She said "I tried to make the Modula pieces into LEGO's".

The designers carried out a *double* design task. They constructed their own design worlds, as they played with and appreciated the materials in different ways, finding different things "interesting", "neat", "noisy", or "disagreeable", selecting a few items, features and relationships from the daunting array of possibilities. And *within* their design worlds, they built particular structures.

From one point of view, the designers' selections were arbitrary, revealing (as in the case of the use or avoidance of the hammer) the influence of idiosyncratic tastes. From another point of view, however, the designers' selections were not arbitrary at all. First of all, selections were keyed to discoveries of particular features of the materials. Mimi found, for example, that by joining individual Modula pieces with clublike connectors she could make "twisty joints", which she said she "allowed herself to use" because "that would be neat". It is true that she just happened to like these joints, but she had to discover them in order to find that she liked them.

In the second place, a certain pattern of appreciations tended to be consistently discernable across the structures made by any given designer: we found that, without knowing ahead of time who had made what, we could identify each designer's structures.

Finally, once the designers had developed their building systems, they generated problems whose solutions could be evaluated objectively, independent of think-so. Rex, for example, once he had assembled his Modula bricks in a 3-dimensional cross around a single cube, wanted to interconnect the 6 ends of the cross. He discovered, however, that there were no rigid pieces of the right size. As he began

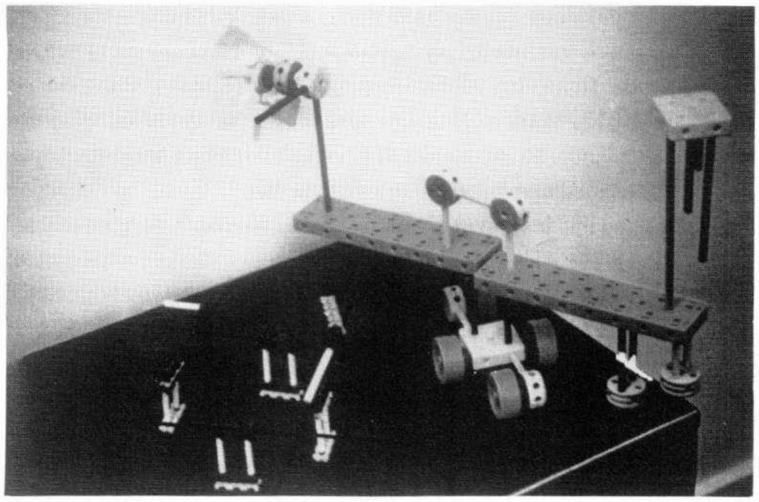


Figure 2. Modula Bricks.

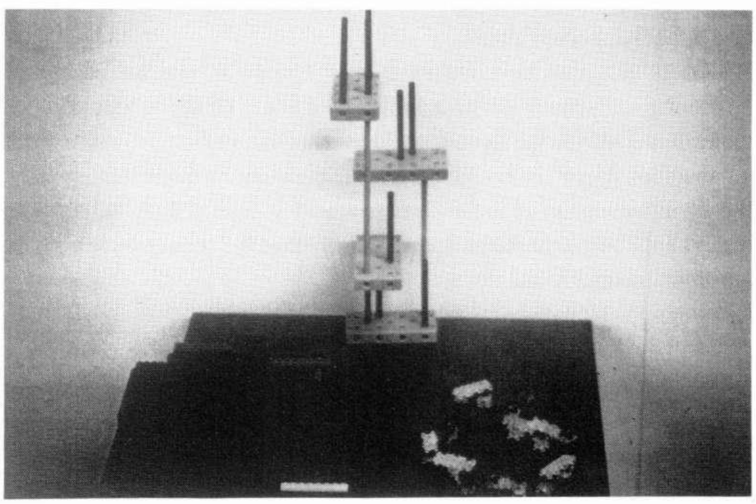


Figure 3. Bob's Constructions.

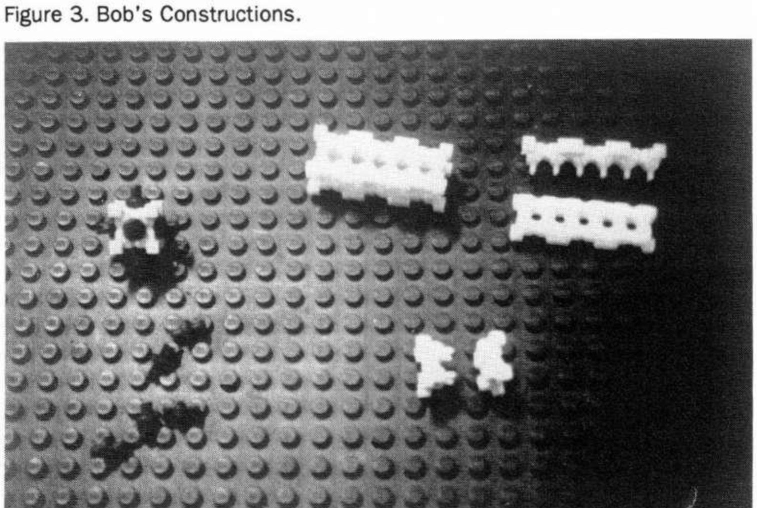


Figure 4. Mimi's Constructions.

to work in a problem solving mode, he got the idea of using the tubes, which he saw as flexible, to connect the ends of the cross—or perhaps he noticed the flexibility of the tubes as he searched for suitable connectors. When he tried out this idea, and found that the tubes were not of the right length, he invented a way of joining short and long tubes in order to make connectors of the right size.

In short, as the designers played with the materials, formed different appreciations of them, developed their own design worlds and began to build their structures, they furnished themselves with functional requirements whose fulfillment was not merely a matter of subjective judgment. Although it was a designer's appreciations that determined which pieces he wanted to connect, his ability to connect them depended, at least in part, on the behavior of the pieces themselves. A designer's subjective (and, in this sense, arbitrary) appreciations shaped the problems he tried to solve. Once problems were set, however, the designer could discover by *move experiments* whether or not he had solved them.

All of this can be contrasted with Simon's famillar image of designing as "search within a problem space". To the extent that designing resembles the examples I have just described, it is clear that a "problem space" is not given with the presentation of design task: the designer *constructs* the design world within which he sets the dimensions of his problem space and invents the moves by which he attempts to find solutions.

Learning in designing

Designing and learning are closely coupled forms of inquiry. Because learning is essential *to* designing, there is a great potential for learning *through* designing. The design process opens up possibilities for surprise that can trigger new ways of seeing things, and it demands visible commitments to choices that can be interrogated to reveal underlying values, assumptions, and models of phenomena.

For example, Mimi, Rex, U-Chin and Bob might, as they reflected on their work, become aware of how their choices of modules and connectors influenced the kinds of structures they produced. They might – and, to some extent, did – become aware of their diverse design worlds, styles of building, and images of a desirable product. Perhaps most important, they might learn to see more deeply into what some design instructors call "the problem of this problem" – the nature of the set of conflicting requirements whose interplay, within a given design world, sets the terms for a design solution. Initial designing may serve in this way as a source of learning preparatory to later designing: having learned, through early probes and experiments, something about the nature of the problem, the designer may go on to make final design commitments of a very different kind than he or she had tried up to that point. Indeed, an entire design project may some-

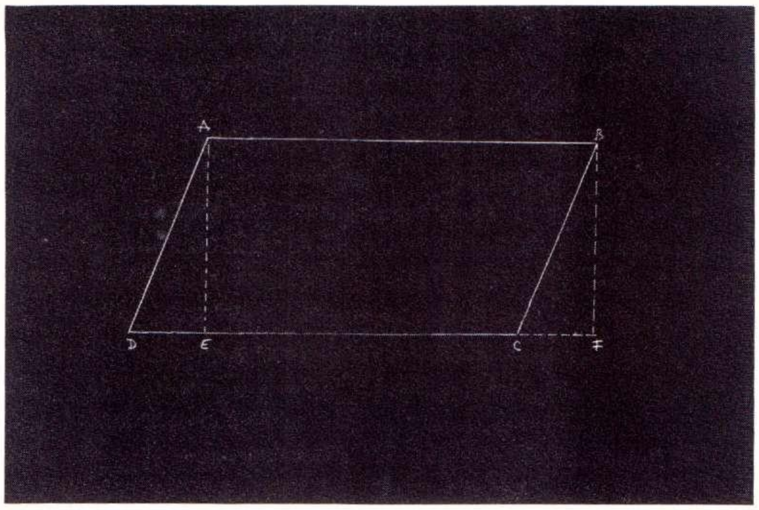


Figure 5: Wertheimer's Parallelogram.

times function as preparation for the execution of future projects. When a designer reflects on the strategies and assumptions that underlie her choices, daring to disrupt them, she may learn critically important things about *herself.* Mimi, for example, might learn, by reflecting on her work, how she had confined herself unawares to a particularly narrow and untested conception of the task at hand. U-Chin, considering his uses of materials in relation to Rex's, might become aware of possibilities for expanding his vision of the technical universe.

Finding the Area of a Parallelogram: Learning as Designing

I have described above some of the ways in which designing, conceived as a process of making things under conditions of complexity and uncertainty, requires or stimulates learning. It is also fruitful, however, to consider learning as a form of designing. I mean here the kind of learning characteristic of ordinary puzzle or problem solving.

Let us consider, for example, Max Wertheimer's well-known analysis of the problem of finding the area of a parallelogram.

Wertheimer points out[8] that how one *sees* the parallelogram opens up, or constrains, the paths to a possible solution. He found that some people to whom he gave this problem were able to see the figure of the parallelogram as containing two triangles, *AED* and *BFC*. If you see these triangles in the figure, and see, further, that the first is an "excess piece" that can be moved over to fill the "hole" of the second, then you can see the parallelogram as a version of a rectangle whose area you may know how to find by multiplying its base times its height. Moreover, you cannot understand the conventional formula – "Drop an altitude from point *A* and multiply it by the base, *DC*." – in such a way as apply it to parallelograms in a variety of different orientations, *unless* you see the figure in this way. (Figure 5.)

In the sample of people to whom Wertheimer gave the problem, some saw the figure in this way and some did not. Moreover, some who did not at first see it in this way came to do so later on. One might be tempted to say that the triangles are *there* in the parallelogram whether one sees them or not. From the point of view of the phenomenology of problem solving, however, the triangles are "there", and interchangeable, only when one constructs a design world (here, a problem solving world) in which they exist.

Working such a problem involves, again, a double design task. In order to solve the problem, the inquirer must restructure the problematic situation. He must construct a figure that includes the relevant triangles, see them as interchangeable, and see the modified figure as the familiar prototype of a rectangle whose area he already knows how to find. In this process, he opens up new problem solving paths, one or more of which he can then follow through to solve the problem.

The construction of a problem solving world is an achievement in itself. The perceived figure of the parallelogram, with its interchangeable triangles, is something the problem solver arrives at through work on the problem. To read it back onto the figure initially given constitutes a species of cognitive historical revisionism that wipes out a crucial component of the problem solving work.

Suppose, however, that someone does not initially see the figure of the parallelogram in a way that makes the formula for finding its area understandable. What if this person's problem solving world does not initially contain the crucial things and relations? How does someone who *does* see them communicate with someone who does not? How can the first party help the second to see the figure, or object at hand, in a new way? What is involved in such a communication across design worlds?

The Silent Game: Communicating Across Design Worlds

In order to explore such questions, I have made use of a variant of a design game developed by John Habraken and his colleagues: the Silent Game.[9]

Designing can be understood as a dialogue of prototype and site. This was the view expressed in the early writings of William Hillier, more recently by John Habraken, and more recently still by Alex Tsonis.[10] According to this view, designers have access to repertoires of prototypes derived in a variety of ways from their earlier experiences. Faced with a particular site and design task, the designer selects one or more prototypes from his repertoire, seeing the site in terms of the prototype carried over to it, seeing the prototype in the light of the constraints and possibilities discovered in the site. This reciprocal transformation of prototype and site suggests a further sense of what it means to say that designing is a reflective conversation with a design situation.

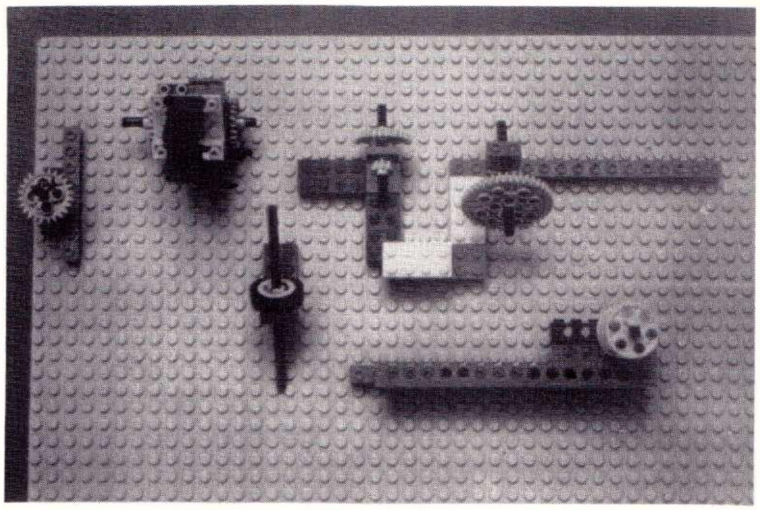


Figure 6. What Fred Built.

Rules, according to this view, are secondary phenomena derived from prototypes. The prototype is prior to the rule derived from it, just as legal precedents in appelate law are prior to the principles of judgment derived from them. As Geoffrey Vickers has observed, lawyers who seek to resolve their disagreements about the principles that should decide a case turn to precedents[11], from which they derive and justify the relevance and priority that should be assigned to principles.

What is involved in grasping the rules inherent in a prototype? May different designers grasp these rules in different ways, according to the different design worlds they have constructed for themselves? And if they do, how can they communicate across their discrepant worlds? The Silent Game provides a context for inquiring into these issues. This game calls for two builders, *A* and *B*, and an observer, *C*. Out of a given set of materials, *A* is asked to make a construction that embodies a rule. It is left openended what a rule is, that decision being left to the builders, whose structures are used as evidence for interpreting their understandings of rules. *B* is then asked to continue the construction according to the rule he attributes to *A*. After *B* has done this, *A* is asked to determine whether he thinks *B* has "got" the rule. If so, *A* is asked to continue building in such a way as to violate the rule; if not, he is asked to continue building in such a way as to reaffirm the rule. While playing the game, all of the parties are forbidden to speak. Afterwards, they are asked to describe what they thought as they played. In the game I shall describe here, LEGO pieces were the construction materials and, as it happened, the players were made up of two kinds of people, architects and computer scientists. I shall consider only one play of the game, in which *A* was Fred, a computer scientist; *B* was Turid, an architect; and the observer was Bonne, also an architect.

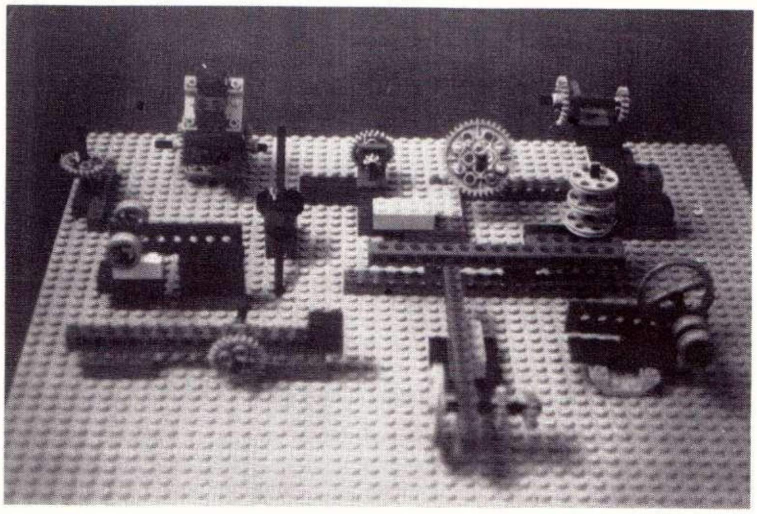


Figure 7. What Turid Built.

About this structure (Figure 6), Fred said, "I was playing with the constraints of LEGO, trying to get relationships that were not horizontal or vertical." "I was trying to get these odd angles [diagonals] in ... then there were things going up and sideways with angles and wheels."

Turid, describing what she had made of Fred's construction, said that she made structures and "added on wheels," noting that "the wheels turned and there was no building on them." (Figure 7.)

Fred, in response, made the following changes: He said, "I added things [pointing to the LEGO pieces he had attached to her wheels, the free-standing yellow piece and the construction next to it] in order to make them have angles." (Figure 8.)

The players were surprised to discover how difficult it was for *B* to grasp the rule of construction intended by *A*, for *A* to infer then what *B* had "gotten," and for *B* to read the meaning of *A*'s responses. In short, the players were surprised to discover how difficult it was for a designer to read the (intended) meaning of a prototype, or to communicate reliably with other designers about its meaning.

The sources of difficulty lay in ambiguities, which were of several different kinds.

First, *A* and *B* were selectively attentive to different features of *A*'s construction. Turid, for example, focussed on "wheels that turned and are not built on", whereas Fred focussed on "odd angles".

Secondly, even when they focussed on the same elements and relations, the two builders often described them differently. What Fred called "odd angles", for example, Turid called "assymmetry, things out of balance".

Thirdly, it was clear that a given construction could be interpreted in terms of more than one rule. Indeed, any given construction seemed

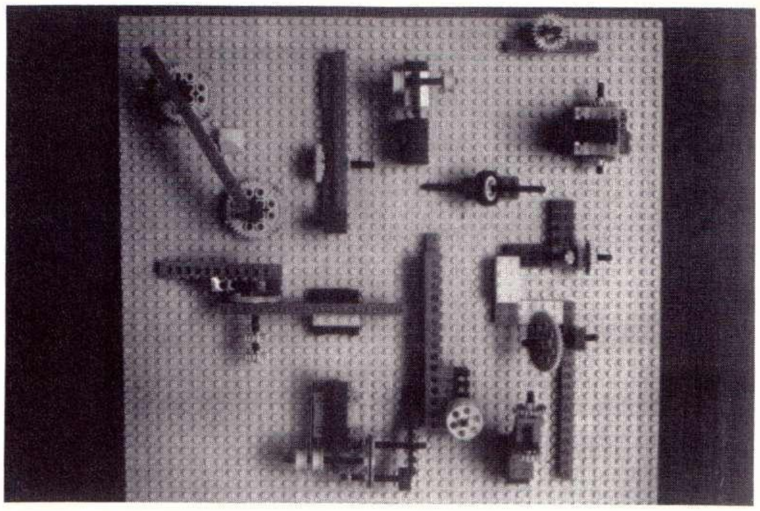


Figure 8. Fred's Changes.

to be interpretable, in principle, in terms of a non-innumerable set of possible rules.

Fourthly, the builder sometimes discovered that he had embodied more in his construction than he had consciously intended. So, for example, when it was pointed out to Fred that he had built all of his constructions with pieces of different colors, he said, "This was not a conscious rule, but I noticed that I couldn't have built anything with all one color".

Finally, the builders sometimes held different conceptions of a satisfactory rule. This point emerged with particular clarity when the builders represented the two fields of architecture and computer science. For example, Fred chose to build structures with "odd angles" because, as he said, he wanted to "violate the constraints built into LEGO"; he was thinking in terms of constraints and their violation. Turid, however, saw the "same thing" in terms of "assymmetry, things out of balance", thinking, not in terms of constraints, but formal qualities. In another play of the game, an architect, playing *B*, discovering that he had misconstrued the rule intended by *A*, a computer scientist, cried out that although the rule intended by *A* had, indeed, occurred to him, he had rejected it out of hand because it seemed to him to be totally absurd.

The Silent game can be used not only to illustrate the divergent interpretation of prototypes but also to illuminate communication among the participants in a social design process. As the builders in the game tried to clear up ambiguities of the kinds described above, through their silent moves and their later verbal descriptions, they made a discovery that seemed profoundly shocking: what they had at first taken simply as the reality of the object turned out to be only one among several possible *views* of that object.

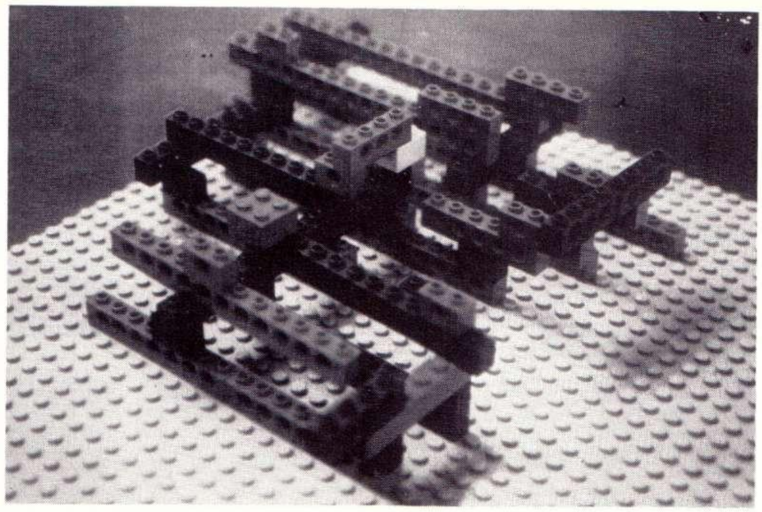
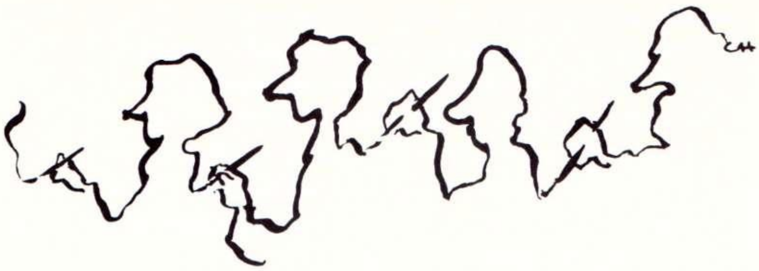


Figure 9. Raj's Second Move.

In his second turn, for example, when Fred saw that Turid had not reproduced his "odd angles", he attached LEGO pieces to her wheels. He explained that he wanted to "make them have angles". This astonished both Turid, the builder, and Bonne, the observer. They had read the rule implicit in Fred's initial structures as "wheels must always be free-wheeling and you can never build on them", and now, as Bonne said, the first thing that Fred did was "to build on Turid's wheels to keep them from moving". When this was pointed out to Fred, he said, "I didn't realize it!" The women in the room then exclaimed, "He blocked her wheels!".

Participants in the game not infrequently became attached to a particular reading of the prototype, and treated an alternative reading as a *threat*, which provoked an angry and defensive reaction. This was sometimes defused by humor, as above. But in another case it was not. Here Raj, in the role of builder *A*, produced a layered structure that he later described as follows: "The bottom layer consists of evenly spaced pieces, the second layer consists of unevenly spaced pieces". Builder *B* interpreted this structure as "an alternation of single- and double-pegged connectors, vertically arrayed." The observer interpreted Raj's structure as an alternation of colored layers: the first layer was blue; the second, red; and the third, blue again. When Raj took his second turn, he made use of a yellow piece. The observer asked why. Raj replied, "Because it was the only piece of that kind that I could find", whereupon the observer blurted out, "I find that absolutely unacceptable!". (Figure 9.)

From the playing of the Silent Game, I draw several lessons about designers' appreciation of prototypes and their communication with one another. First of all, prototypes are inherently ambiguous, subject to multiple readings, each of which involves the construction of a



different design world. Moreover, moves that are intended to clear up ambiguities resulting from differences in appreciation tend to be ambiguous in their own right. Finally, the achievement of a convergent, collective reading of prototypes depends on reciprocal reflection among designers – reflection on objects, moves and descriptions – which may be subverted by the participants' attachment to particular readings and their defensive reactions when their readings are called into question.

Conclusion: Some Implications for Teaching and Learning

From my analysis of examples like these—the MIT students' work with construction systems, Wertheimer's study of the problem of finding the area of a parallelogram, and the playing of the Silent Game – I draw several conclusions about teaching and learning.

Learning to design

In certain respects, these stories reinforce the value of traditional approaches to education in the design professions. The design studio plunges students into complex and uncertain design situations, before they know what they are doing. It brings them into direct contact with materials. It habituates them to the use of virtual worlds for designing, such as sketchpads, tracing paper, and scale models of various kinds.

But not all design instructors are equally adept at helping students to reflect on the design worlds they construct for themselves, the range of prototypes to which they have access, or the ambiguities inherent in their design moves. Design instruction takes on a different (and, I think, more illuminating) quality when the design instructor sees designing as a conversation with the materials of a situation and helps the student to make that conversation a reflective one.

The possible roles of designing in education

Design tasks, in the narrow sense – the making of concrete, material objects – have a great deal of potential for use in educational contexts that, on the surface, bear very little relationship to the traditional design professions.

When students make things, they reveal what they know, spontaneously and intuitively, in action. Not infrequently, they also reveal gaps between their knowledge-in-action and their formal understandings of school knowledge, such as the mathematical equations they are able to manipulate or the physics formulae they are able to reproduce. For example, students who are perfectly capable of stating Newton's three laws of motion are often unable, when they try to build a mechanism that works, to *see* or *feel* the operation of Newtonian mechanics in the behavior of the mechanism.

Designing material objects, because it demands that the student make commitments to particular shapes and arrangements of things, surfaces the student's knowledge-in-action and thereby makes it, and its relation to school knowledge, vulnerable to reflective inquiry. Moreover, the designing of material objects has the potential to yield surprises. Students may be shocked to discover the unintended consequences, or meanings, of what they have produced. If they are encouraged to reflect on such surprises, they gain an opportunity to learn about the tacit models, or the unexamined design worlds, that underlay their spontaneous design moves. They may also learn to move back and forth across multiple representations of phenomena they had seen in only one way as "the right answer" or "the way things are".

These observations also have a bearing on the educational uses of the computer. For example, in a recent study of Project Athena, MIT's large-scale experiment in the introduction of computers into undergraduate education, Sherry Turkle and I found that some of the most promising *uses* of educational software (sometimes, in contrast with the software builder's intended use) were ones in which the computer functioned as a design environment, a "microworld" in which the students were able to discover and interrogate the surprising consequences of their design moves.[12]

Teaching and learning as a reflective conversation with the situation

In a sense more generic than either of the ones described above, the teaching/learning process can be seen as a design transaction, a reflective conversation with the materials of a situation.

In this sense, the Silent Game becomes a metaphor for teaching and learning. A teacher, striving to help her students understand new material, is limited to the actions of "showing" and "telling". She can offer descriptions and make demonstrations. But her descriptions and demonstrations are always inherently subject to ambiguity. They almost never succeed in conveying exactly the meanings she intends, and convergence of meaning between teacher and student is one of the *least* likely outcomes of the educational process.

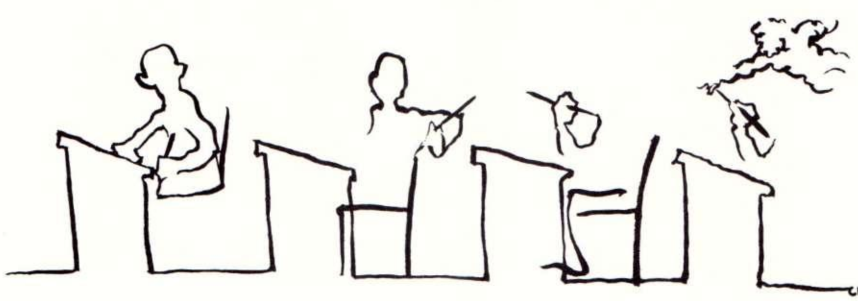
A teacher who is aware of this predicament may come to think of teaching and learning as, at best, a collaborative, communicative process of design and discovery. She would see it, then, as what the philosopher, David Hawkins, has called a "dialogue of I, Thou and It''.[13]

Such a dialogue is both literally and metaphorically a "conversation". Within it, both teachers and students become designers. In relation to "It", the material at hand – for example, the figure of the parallelogram – teacher and student seek to construct a view of the problematic situation that opens up new formulations of the problem and new paths to solution. In relation to each other, "I" and "Thou", they face a problem of communicating across divergent design or problem-solving worlds. Their task here is one of reciprocal reflection-in-action.

Within such a conversation, a student might try to make sense of an unfamiliar problem or puzzle by asking "How can I discover what this teacher means by what she says and does? How can I discover the way of seeing things that underlies her messages to me? And how — especially when I am confused or stuck – can *I* discover how I am seeing these materials, this situation? How do I become aware of alternate ways of seeing them?"

A teacher, struggling to help her students make new sense of the material, would try to see things from the position of "that kid over there". She would ask herself, for example, "How must that kid be seeing things in such a way as to lead him to say and do what he does? What possibilities and limits inhere in his way of seeing?" The teacher would try then, as Jeanne Bamberger and Eleanor Duckworth have put it, to "give the kid reason".[14]

She might go on to help the kid discover other ways of seeing things, other paths to solution, especially the privileged views and paths embedded in "school knowledge" (for example, the formula for finding the area of a parallelogram). She might coach him to build up multiple representations of phenomena and cultivate the ability to move back and forth among them. In order to do this, she would need to interrogate her own understandings and hang onto her own present or past confusions and the steps by which she may have arrived at a new and fruitful way of seeing things.



Notes & References

1. Herbert Simon, *The Sciences of the Artificial*, Massachusetts Institute of Technology Press, Cambridge, Mass., 1976.
2. I use this term in John Dewey's sense. See John Dewey & Arthur F. Bentley, *Knowing and the Known*, Boston: The Beacon Press, 1949.
3. I use the terms "design world" and "worldmaking" in the spirit of Nelson Goodman's *Ways of Worldmaking* (Goodman, 1978).
4. John Dewey, *Logic: The Theory of Inquiry*, New York: Holt, Rinehart, and Winston, 1938.
5. Edmund Carpenter, *Eskimo*, (identical to *Explorations*, no. 9; Toronto: University of Toronto Press, 1960), pp. 66–67.
6. David Billington, *The Tower and the Bridge*, Basic Books, New York, 1983.
7. John Habraken, *The Appearance of the Form*, Atwater Press, Cambridge, Massachusetts, 1986.
8. Max Wertheimer, *Productive Thinking*, (Chicago: University of Chicago Press, 1945).
9. This variant of the Silent Game was developed together with William Porter, Edith Ackermann and Bonne Smith, in the course of our Design Research Seminar, Fall, 1990.
10. See William Hillier & Andrew Leaman, "How is Design Possible?", *mimeo*, 1973 i John Habraken, *op.cit.* Alex Tsonis made a similar point in the course of a lecture given at the International Conference on Design Research, Delft, The Netherlands, in June, 1991.
11. Geoffrey Vickers, *Value Systems and Social Process*, Tavistock Press, London, 1968.
12. See Sherry Turkle & Donald Schön, *Project Athena at MIT*, MIT, *mimeo*, 1990.
13. David Hawkins, *The Informed Vision*, Agathon Press, New York, 1974.
14. See Jeanne Bamberger & Eleanor Duckworth, *The Teacher Project: Final Report to the National Institutes of Education*. Massachusetts Institute of Technology, 1979 (*mimeo*).

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Illustrationer: Cecilia Häggström