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COMPUTER EXPERIENCE AND COGNITIVE DEVELOPMENT:
A CHILD'S LEARNING IN A COMPUTER CULTURE
by Robert. W. Lawler.
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One characteristic of our culture is the tendency to think in terms of stereotypes. A common stereotype, that of the brilliant but unfeeling scientist – like Mr. Spock in the television series Star Trek – may have some basis in reality but is wildly overgeneralized. Many people become afraid of science because they feel, on some level, that learning science would interfere with their emotions, overlooking the fact that there are many deeply human scientists who bring energy and enthusiasm to their work and to their lives.

One such scientist is Robert Lawler, the author of *Computer Experience and Cognitive Development*, whose book grew out of one of the most notable efforts by a research team to do science in a humanistic way. Between 1975 and 1981, Lawler studied with the Logo Group at MIT under the direction of Seymour Papert. Following his graduation, Lawler remained at MIT as a research scientist with the Logo group. The central objective of the Logo group has been to exploit the new opportunities in mathematics and science education made possible by the computer revolution. But, unlike many other researchers in computers and education, they have concentrated on creating computerized learning environments rather than instructional programs. In Papert's words, these researchers believe that "learning is best when the learner is in control." *Computer Experience and Cognitive Development* is a detailed report of Lawler's descriptive investigation of children's learning within such a computer-supported environment.

In discussing Lawler's work, it is helpful to begin with the two central concepts in his analysis of children's learning, the notion of bricolage and the idea of a microworld. In colloquial French, "bricolage" is the work of the bricoleur, the kind of person who is gifted at fixing things—a tinkerer. In recent decades, however, the concept of bricolage has acquired theoretical significance within the social sciences as a result of the influence of the theories of French anthropologist Lévi-Strauss (1962).

Lévi-Strauss observed that the craftspersons of the nontechnological societies he studied seemed to think in a way which contrasts sharply with the Western ideal of technical rationality in scientific thinking. The Western technologist may set an objective, formulate a plan, and then execute it, the ends always preceding and determining the means. In traditional societies, things often happen the other way around, with the means determining the end and the process of construction taking precedence over the preconceived definition of the product. In such situations, planning serves a different role than it does in scientific rationality. Plans emerge and change, growing out of the changing nature of the situation, as the constructive process continues, and what was earlier an end becomes a means in the evolving plan.

Observing different cultures helped Lévi-Strauss to highlight and define bricolage as an alternative to the Western ideal. Lawler points out that while bricolage may be contrary to our cultural ideal it is nevertheless quite common in our practical use of thinking. In fact, bricolage may be the general case of which scientific rationality is a special case.

Thus, Lawler wishes to make an argument in developmental psychology similar to that of Lévi-Strauss. According to Lawler's observations, in learning, means tend to govern ends much more often than the reverse. It is not that children learn in order to earn high grades or to win social approval. Rather, they learn because it is human nature to learn. Children follow their interests and set goals for themselves in accordance with the needs of the situation in which they are involved. The rewards, when they come, are a result rather than a cause. Lawler would wish to argue that this natural mode of learning is more important to understand than that which is motivated by the formal abstract considerations of the academic world.

Lawler uses the term "bricolage" in two senses. One part of what Lawler sees as bricolage is having a kind of mechanical or procedural skill, such as skill at Logo programming on the part of a child. The other part is a certain intellectual style. In suggesting the latter, Lawler is asking us to broaden our conception of "intellectual style" to include qualities of the *bricoleur-type* handyperson as well as of the academic intellectual. Lawler distinguishes the thinking of the handyman from that of other people who work with their hands, such as assembly-line workers. The distinguishing characteristic is that a handyman works by intuition rather than from design. The difference between the orderly top-down methodology of engineering and the bottom-up approach of the handyman lies in the reversal of means and ends discussed above: for the engineer and social planner, the end determines what means should be chosen; for the handyman, the means at hand determine the methods used and help to shape the end that will be reached.

The second central concept in Lawler's work is the notion of a microworld. Lawler, like a number of other contemporary thinkers in cognitive and developmental psychology (Carey, 1985; Gardner, 1983; Minsky, 1985), adopts a modular view of intelligence. Rather than viewing the mind as a single comprehensive structure, he sees it as made up of numerous, somewhat independent structures that he calls *microworlds*. Lawler introduced the idea of a microworld to refer to a kind of cognitive structure which is bound to a specific environmental context. He sees microworlds as fundamental units of cognitive organization, and he believes that the interaction among microworlds, their differentiation and reintegration, is a fundamental process of cognitive growth.

While he accepts the views of developmental psychologists, and most especially of Piaget, in their most general terms, Lawler feels that they have underestimated the role of experience and the environment in development, as a byproduct of their quite justifiable emphasis on the importance of the activity of the subject. Thus, he is critical of Piaget's practice of seeing the mind as organized according to scientific and philosophical categories, such as space, time, number, and causality, because it does not seem to take into account the structure of the environment as the child experiences it. Lawler feels it is more accurate to say that the mind is organized around the concrete experiences of everyday life. Indeed, the way people think about number or causality may differ greatly from one context to another.

The ideas of bricolage and microworlds are linked by Lawler's research, which examines the details of the child's bricoleur-like activities in the process of organizing and reframing microworlds around specific objects in the environment. The computer, for Lawler, is prototypic of an object in the environment around which knowledge can be organized. A central question for him, of practical as well as theoretical importance, is how knowledge, represented as part of a computer-based microworld, interacts with microworlds associated with other parts of a child's experience.

Lawler is a self-described bricoleur in his approach to his own research, using a case-study method and following his own intuition in generating and evaluating hypotheses about children's learning. There surely are risks in relying too heavily on intuition—those of us who conduct scientific research understand these problems well. But a simple "dust-bowl empiricism" rarely yields the kind of creative results that are needed to move science in new directions. Lawler's research methods offer a lesson in the skillful and productive use of inductive methods. The work demonstrates the sort of contribution which can be made when an intelligent and open mind takes a fresh look at naturally occurring behavior in order to seek and identify any orderly patterns which emerge. For a six-month period Lawler observed and recorded, as well as humanly possible, everything done by his six-year-old daughter Miriam. He then pieced together his observations into an explanatory structure, using concepts from Piaget's original writings and from artificial intelligence. The resulting research report provides many valuable and new insights about the nature of children's learning.

In the book's most interesting chapter, Lawler combines the concept of a microworld with bricolage, to analyze Miriam's understanding and acquisition of elementary arithmetic. First, he demonstrates that Miriam uses very different methods of adding in different empirical contexts. Second, he shows that bricolage provides her with a method to expand her understanding.

In the case of Miriam's learning of addition, Lawler distinguishes three separate microworlds: the count world, the money world, and the decadal world. Each microworld is an internal representation of some particular real-world context. Lawler believes that he can explain the development of Miriam's thinking about addition in terms of the growth and interaction of these microworlds.

Each microworld contains some knowledge of adding, but a kind that can only be applied in a particular context. The count world represents knowledge of adding through finger-counting. Its limitation is that people have only ten fingers, so that the count world is useful only in adding very small numbers. The money world represents addition in terms of a collection of well-known sums. These are sums that recur repeatedly for Miriam when she buys things, because of the peculiarities of how objects are priced. For example, since Miriam's favorite gum cost fifteen cents a pack, and since she liked to buy two packs at a time, she knew that fifteen plus fifteen equals thirty.

The decadal world is like the count world except that it allows the addition of two-digit numbers. This kind of addition is accomplished by concatenating sequentially two count-world additions. For Miriam, to add fifty-five plus twenty-two was equivalent to two concatenated additions of five plus two, and to add fifty-five plus twenty-six was equivalent to one addition of five plus two concatenated with a second addition of five plus six. This method yields the correct answer to the first of these two problems, seventy-seven (perhaps more accurately read "seven:seven"), but an incorrect answer to the second problem, seven hundred and eleven (perhaps read more accurately "seven:eleven"). Since, in the decadal world, the two additions cannot interact, addition with carrying is impossible.

The decadal world grew out of Miriam's experience with the computer. Lawler created a computer game for her called "Shoot" which involved aiming and firing an image of a projectile at a target. "Shoot" uses the turtle graphics system associated with Logo (the childrens programming language developed by Papert), in which changes in orientation are represented in terms of Euclidean degrees, from 1 to 360. To adjust her aim, Miriam often was forced to add angles, of which many of the most useful values, such as 60, 90, and 180, are multiples of ten. To add sums such as 50 plus 20, Miriam would strip off the zeroes, use finger counting to find five plus two, and then add on a single zero.

A turning point in Miriam's ability to perform addition came one day when she brought to her father a problem from her older brother's arithmetic homework.

> Miriam: Dad, twenty-eight plus forty-eight is seventy-six, right?
>
> Bob: How did you figure that out?
>
> Miriam: Well twenty and forty are like two and four. That six is like sixty. We take the eight, sixty-eight (and then counting on her fingers), sixty-nine, seventy, seventy-one, seventy-two, seventy-three, seventy-four, seventy-five, seventy-six.

In Lawler's opinion, this incident has important theoretical significance in two ways. First, Miriam was able to discover on her own how to carry. That in itself would be significant, since the algorithm for carrying is normally considered an idea that children need to be taught in school. This finding would support the opinion of Lawler and Papert that children can learn much more on their own than we usually recognize. Second, and of greater theoretical importance, is the fact that Miriam discovered how to carry by *combining* knowledge from two microworlds: the decadal microworld and the count microworld. On the basis of this incident, and other supporting evidence, Lawler argues that the process of separation and reintegration of microworlds explains much of the progress in children's cognitive development.

In introducing the chapter on microworlds, Lawler cites Piaget: there is no development without structures and there are no structures without development. This principle is especially clear in Piaget's (1947/1950) epigenetic view of development in terms of the biological metaphor of differentiation and coordination. This analogy figures prominently in Piaget's account of cognitive growth. Most people are familiar with instances of differentiation and coordination from biology. Mitosis or cell division would be an example of cell differentiation; the formation of tissue could be seen as an example of coordination. Piaget believed that cognitive structures share with biological structures, such as cells and tissues, the ability to reproduce and form themselves into higher order units.

Lawler's account of development in terms of separation and integration of microworlds is really an elaboration of Piaget's biological metaphor for structural change. However, Lawler's theory differs from Piaget's in two ways. First, he sets aside Piaget's highly integrated conception of cognition, according to which, at a given stage of development, children's thinking always has the same underlying structure. In Lawler's opinion, structure is bound to particular contexts. In other words, a particular organization develops in relation to a specific environmental reality and relates to the specific context of that reality. The multiplicity of such contexts argues against structural unity.

The other point of departure from Piaget is Lawler's richer, more detailed, and more concrete characterization of mental structures. Piaget characterized structures, such as the *groupement* or the INRC group, in the most abstract and general mathematical properties, such as closure, associativity, and reversibility. In contrast, Lawler characterizes microworlds in terms that are highly concrete and specific, such as his characterization of the money world in terms of the specific coins that Miriam used. One may therefore say of Lawler, as Papert says of his own work, that he is trying to stand Piaget on his feet. In other words, he is trying to retain what is valuable in Piaget, but in a form that makes contact with our ordinary intuitions about ourselves.

The style of Lawler's research is also reminiscent of parts of Piaget's corpus, especially of Piaget's classic study of intelligence in infancy, which was also an observational study of his own children (Piaget, 1936/1952; 1947/1950). One is impressed with the scientific quality of Lawler's work, and with him as both experimenter and theorist. As an empirical observer, Lawler is thorough, accurate, and admirably objective. As a theorist, his use of the concept of microworld provides a convenient unit for ordering data at the level of functional analysis, reminiscent of Piaget's most useful organizing concept at the structural level, the developmental stage. Furthermore, Lawler brings to his writing an unusual breadth of learning, reminiscent of Piaget's scope.

However, regardless of whether the reader is persuaded, or even interested, by Lawler's theoretical perspective, this book provides a richer body of empirical data about children's learning than any other comparable study. In addition to the chapter on children's arithmetic, there are interesting chapters on how children learn computer programming, and on the role of social interaction in learning to play games of strategy.

Nevertheless, to see this book primarily as a source of data about children would mean not taking seriously Lawler's more fundamental purpose. It is the intention of its author that the conception of human nature articulated in *Computer Experience and Cognitive Development* will become recognized in psychology as a new and significant theory. Just as Chomsky (1975) hopes that the study of language may offer a "mirror of the mind"—insight into human intelligence and into what is most essential about human nature—so Lawler has a similar hope in regard to the study of children's learning.

Lawler's very attempt at a comprehensive interpretation of mind in terms of cognition is evidence of an important change in how we think about ourselves. Lawler believes that intellect and cognition are just as central to human nature as personality and affect. It should follow, therefore, that the whole person is just as much the domain of cognitive theory as of other theories such as personality theory. Furthermore, our major theories of personality are open to challenge on the grounds that an account of the entire person should surely provide a better understanding of our cognitive half than any of them currently do.

In the spirit of a general theory of mind, Lawler makes a number of important assertions which ought to prove fruitful for further research. One of these is that knowledge is organized around concrete task domains, such as Miriam's count, money, and decadal microworlds, rather than into subjects, such as reading and arithmetic, or categories such as space, time, and number. Another is that it is natural for means to precede goals and ends, rather than for people to choose their means as a way of achieving existing goals. A third assertion is that, contrary to Piaget's position, abstract formal thought does not develop out of concrete thought, but rather is structurally and developmentally distinct.

Although Lawler cannot, and does not, claim that any of these assertions are proven by his data, the evidence which he provides is very suggestive in favor of his conclusions. Furthermore, in providing this evidence, he argues persuasively for the case-study method by which he collected it, on the grounds that it gives us a method for generating interesting and significant theories and hypotheses both disciplined and stimulated by a rich array of naturally occurring human behavior. This method of hypothesis generation differs from the method of researchers who work from a suggestive metaphor (like computer models of intelligence) and also from the method of those who simply react against, or elaborate upon, some previous research.

All three methods have their value. Indeed, Lawler uses all of them. But the case study method has a special strength. The other methods provide for the gradual and progressive growth of knowledge, by providing a category, or set of categories, through which the researcher may view and understand reality. The advantage of the case-study method is that it permits a more complex and dynamic series of interactions with the situation under study—which seem essential for the emergence not only of new data but of new categories of thought. Thus the experience through which the concepts of bricolage and of a microworld developed in Lawler's own mind is like the process through which the concept of carrying in addition emerged in the mind of his daughter Miriam.

There are, however, two important issues in Lawler's analysis which, in the future, the author will need to address. One is the issue of the social component of learning. According to Lawler's own analysis, Miriam discovered her method of addition with carrying during an exchange with her father. As Lawler describes it, he is the one who brought the count-world algorithm to Miriam's attention, at a time when she was thinking in terms of the decadal world. If the researcher had been Vygotskian rather than Piagetian, her learning surely would have been interpreted as that of a child internalizing the thinking of her teacher, rather than as an emergence or personal discovery.

The other issue which needs to be addressed is that his case could have been stronger were it not for a minor problem in methodology. His research design should have included a second and even a third subject, to permit internal replication. Piaget recognized that this small amount of additional work was worth the effort. Results drawn from three subjects are much more likely to be broadly replicable than results from one. In addition, the subject whom he studied would not in any case be considered typical. Her Stanford-Binet IQ places her in the top 1 percent of the population. Even if this were not the case, she comes from an intellectual family where the parents are highly educated and likely to spend a great deal of time imparting that education to a child. Such conditions, of course, raise questions about the generality of the research. In fairness, however, it should be noted that Lawler has addressed this problem in his subsequent research.

Nevertheless, to appreciate the achievement that Lawler's research represents, it is useful to place it within the historical context from which it comes, the developing discipline of cognitive science. During a talk given in the late 1970s, Papert offered a framework for understanding the history of cognitive science. He suggested that up to that time, the discipline had moved through three periods, which he called the classical, the romantic, and the modern.

The classical period lasted from the mid-1950s to the late 1960s, beginning with the Dartmouth Conference of 1956. Research during the classical period was dominated by the belief that thinking is essentially a logical process, and by a particular interest in explaining how people solve problems in formal mathematics. Newell and Simon's (1963) computer simulation program, General Problem Solver, is typical of this period.

The romantic period lasted from the late 1960s to the late 1970s. Interest shifted from formal and logical reasoning to commonsense inference, and especially to the thinking of children. Researchers became willing to speculate more freely; this is the time when there was the greatest interest in Piaget. Minsky's (1975) frame theory is typical of the romantic period.

The modern period was just beginning in the late 1970s. It represented a reaction against the romanticism of the early 1970s, an interest in working out the technical details of proposals which had previously remained speculative, and in general in a return to basics. During this period, there was an unprecedented interest among cognitive scientists in the brain. Marr's (1982) detailed work on the visual system is typical of the modern period.

If one accepts this scheme, then Lawler's book, along with the work of others, such as the recent studies of children's mathematical development (Brown & Burton, 1978; Ginsburg, 1983) may perhaps be viewed as representing the beginning of a new era, one that may be called post-modernist cognitive science. In this work, one sees a greater interest in applied problems and in what most people perceive as real-world cognition, in contrast to the concerns of earlier periods which now may seem theory-driven. Although not present directly in Lawler's work, there appears to be, as well, an increasing interest in understanding how affect influences cognition. From the perspective of the long-term development of cognitive science, then, *Computer Experience and Cognitive Development* may represent a transition from theory to reality and lead to an appreciation of the complexity and individuality of real children living in a real environment.

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