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An interview with Robert Lawler

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Robert Lawler is now retired but still working on the projects that have engaged him for a lifetime. He lives in Lake Geneva, Wisconsin, USA and his email for correspondence is lawleremail@gmail.com.

Abstract

Robert Lawler is one of the key figures in the development of thinkable models and educational games. In this interview, dedicated to Seymour Papert, Marvin Minsky and Oliver Selfridge, he comments on his research notes and provides fascinating insights into the early days of artificial intelligence applications in education.

After a distinguished career working on thinkable models and educational games, Robert Lawler is now engaged on his retirement project. We met on a trip to Taiwan in September 2011 to attend the Edutainment 2011 Conference and spent a considerable time talking about his work and mutual friends.

Nick Rushby (NR): You've been in this business a very long time now, how did you first get involved in artificial intelligence (AI) and learning?

Robert Lawler (RL): In mid-life, at lunch with a former Caltech undergraduate classmate, I mentioned I was bored with my career as an IBM Systems Engineer and considering a return to the academic world. He asked what problems interested me. "How can something so insubstantial as an idea become a part of a person?" (No wonder that I was delighted later when I encountered Warren McCulloch's essay "What is number that man may know it, and man that he may know a number?" (McCulloch, 1963)). I added that creating databases and writing programs was installing knowledge in computers and that our experience with the new computing technology might help us—by contrast—better understand this essential aspect of being human. He responded, "Do you know Minsky?" Since I did not, he explained his question.

"Recently Feynman tried to recruit Minsky for Caltech, but couldn't get him to leave MIT. If these issues interest you, you'll have to move to Boston." I did so, entering MIT's Center for Advanced Engineering Study to explore ideas in Artificial Intelligence, the new research area. Minsky was the first of my three heroes.

I took several graduate courses, but most interesting was the outcome of my registering for a course listed by Seymour Papert, which he decided not to offer that semester but had failed to cancel. I was the only student. So we met in a weekly tutorial during the term, to my great benefit. He is the second of my heroes. Papert's reading list included books that addressed directly my central question. Warren McCulloch's *Embodiments of Mind* (McCulloch, 1963) (to which Papert wrote an important introduction) and Piaget's *Biology and Knowledge* (Piaget, 1974), which showed the perspectives and research directions where different intellectual traditions of Cybernetics and Genevan Developmental Psychology made contact with each other. From the spectrum of the Piagetian corpus, Papert recommended books he considered Piaget's best and most representative of his varied network of enterprises. To these, he added *The Developmental Psychology of Jean Piaget* (Flavell, 1963), less for the characterization of Piaget's thought than for the comprehensive presentation of Piaget's experimental studies at a useful level of detail. Papert had been "Piaget's Mathematician" for about 5 years and was described by Piaget during that period as an "ideal colleague" (Piaget, 1997).

NR: For those who are not familiar with the background to turtle geometry, AI and education, it might be helpful to give us some background.

RL: Papert originated the MIT Logo Project within the Artificial Intelligence Laboratory, based on the Logo Programming Language, turtle geometry, and the aim of introducing powerful ideas to people through processes of discovery predictable in that interactive physical and programming environment.

Logo is, in fact, a dialect of Lisp, simplified for use by children and novices, which had been developed at Bolt, Beranek, and Newman in Wallace Feurzeig's project, to which Daniel Bobrow and Cynthia Solomon were major contributors, as was Papert in his capacity as consultant to the effort. Turtle geometry was a list-focused extension of Logo using output commands to drive a robot, based on Grey Walter's robot "turtle," with commands for movement in a body-centered geometry.

The pedagogical foci included relating geometry and programming ideas to users' body knowledge and relating recursion to repeated action. What might be a powerful idea? If one considers recursive procedure invocation (a notion central to Lisp, and thus in Logo) as an inverse of mathematical induction, the educational aim then could be to provide people with a concrete experience of this class of ideas, through which they would more easily understand mathematical induction encountered in later studies. On an everyday basis, I enjoyed playing with children, introducing the Logo Programming Language to them, and also trying to observe and understand what they learned from the objects and activities they played with. This included my own children as well as others. My 8 years with IBM in teleprocessing programming, database design and multiprocessor operating system modification, prepared me well enough to make computer-based game environments for children to play with.

Tracing the development of ideas in the minds of children as an engaged experimenter could be seen as a kind of cognitive anthropology where I followed Flavell's suggestion to explore development through a integration of the data-rich studies of Ecological Psychology with structuralist notions as found in Piagetian Theory (as best represented by Barker & Wright, 1954).

Thinking about this drew on my understanding of Levi-Strauss' characterization of problem solving of the natural mind as "bricolage," (Levi-Strauss, 1966) an idea possibly better appreciated through its presentation in Francois Jacob's *Evolution and Tinkering* (Jacob, 1977; and see also Jacob, 1994).

On the other hand, I had come to MIT to study with Minsky who was proposing a more functionally compatible kind of structuralist thinking. He defined one aim of the lab's research to be "understanding the development of the control structure of mind." I took up that goal as my personal challenge, and so I still consider it. I was most fortunate to discover an environment where my personal research quest was entirely compatible with a technical thrust for improving education.

NR: At that time there was a spectacular change in computer technology. How did that affect AI in education?

RL: Computer developments from the 1970s into the 1980s were completely stunning. The machines moved from core memories, to transistors, to large-scale integration technologies and the terminology describing what we were creating in the computers went from the "problem space" simulations of Newell and Simon, to virtual worlds of Winograd's language experiments on the PDP-10, to PDP-11 miniworlds, to TI-99 and Apple II microworlds. In my early use of "microworld," I thought of the reconstruction within individual minds of aspects of the macroworld of everyday life, in the sense that man is a microcosm reflecting the macrocosm. In writing *Designing computer based microworlds* (Lawler, 1982), I adopted the terminology Papert made popular in his book *Mindstorms* (Papert, 1980) and summarized my focus in the project's agenda, connecting it to Piaget's most lucid exposition of his educational ideas (Piaget, 1970) beginning from specifying three questions we must be able to answer to claim that we have a science of education, thus:

1. What is in the child's mind?
2. How our actions change what is in the child's mind?
3. Why some changes last a longtime and others do not?

Item 2 of that list may seem to suggest a focus on "instruction," but that is not the whole story. Based on his theories, his case studies and experiments, Piaget defines the objectives for constructivist education by contrast with the traditional practice:

> If we desire to form individuals capable of inventive thought and of helping the society of tomorrow to achieve progress, then it is clear that an education which is an active discovery of reality is superior to one that consists merely in providing the young with ready-made wills to will with and ready-made truths to know with.

Who would be happy with any less result? But good goals do not imply easy achievement. Teachers face a dilemma when they try to move children to do schoolwork that is not intrinsically interesting. Children are induced to undertake the work either by promise of reward or threat of punishment, and in neither case do they focus on the material to be learned. In this sense, the work is construed as a bad thing, an obstacle blocking the way to reward or a reason for punishment. Kurt Lewin explores this dilemma in *The Psychological Situations of Reward and Punishment* (Lewin, 1935). Papert presented computer-based microworlds as a general solution to the problem of motivation. One argument for his position ran as follows: learning is often a gradual process of familiarization, of stumbling into puzzlements and resolving them by proposing and testing simple hypotheses in which new problems resemble others already understood. Microworlds are in essence "task domains" or "problem spaces" designed for virtual, streamlined experience. These worlds encompass objects and processes that we can get to know and understand. The appropriation of the knowledge embodied in those experiences is made possible because the microworld does not focus on "problems" to be done but on "neat phenomena"-phenomena that are inherently interesting to observe and interact with. With neat phenomena, the challenge to the educator is to formulate so clear a presentation of their elements that even a child can grasp their essence. A well-designed computer microworld embodies the simplest model that an expert can imagine as an acceptable entry point to richer knowledge. If a microworld lacks neat phenomena, it provides no accessible power to justify the child's involvement. We can hardly expect children to learn from such experiences until they are personally engaged in other tasks that make the specific knowledge worthwhile as a tool for achieving some objective. This amounts to an appropriate shifting of accountability from students (who have always been criticized for not liking what they must learn) to teachers, those who believe that their values and ideas are worth perpetuating.

NR: So what then was the challenge of artificial intelligence?

RL: Colleagues in Artificial Intelligence were thrilled when specific tests proved that a machine could do a task formerly judged only possible for humans. My attitude was different:

> "Machines already exist which can do calculus and chemistry problems better than any man. If we make a machine which can construct for itself a better mind than any man can, has not the work of our hands superseded the work of our loins?" (Lawler, 1984, unpublished.)

This stance led me to ask what, specifically, can people do that machines cannot do now? And that question brought me back to an evening as a student at Caltech:

When I was an undergraduate, it was once my privilege to spend an evening with a man, Richard Feynman, known more for his work in physics than in psychology. Nonetheless, what Feynman said about thinking and learning deserves consideration. When asked how he got to be so good at solving problems, Feynman offered a description of his practice as an undergraduate student which is fundamental to the view I developed. He recalled that whenever he actually solved a new problem—by whatever method he could manage—his exploitation of that small victory had only begun. He would then step back from the problem and try to see what other ways of looking at it were possible and to ask in what other formalism one might describe the problem. He would then work through the "same" problem to its solution in those secondary formalisms using the primary solution for guidance (Lawler, 1996).

Feynman's reflection upon these different schemes of representation, his developing understanding of the relation of one to another and the details of their intertranslatability led to his mastery of selection among and application of varieties of descriptions and formalisms.

In Feynman's story, we can see a way of looking at the balance between algorithm execution and problem recognition. Depth is needed to push through analysis with rigor. Breadth pays. The exploration of alternative representations and prosecution of problem solving in their terms is the activity that leads to mastery of individual representations and understanding of which is the best fit among those possible. This suggests the possibility of a new division of labor. We people need all the help we can get. Whatever help machine intelligence can give us should be exploited for the exhaustive exploration of fecund problems in order that the human learner can improve the ability to recognize problems and select the best representational framework for addressing any new problem encountered. Excessive dependency on mechanized knowledge can be avoided by following a proposal of Feurzeig (1987) to design intelligent microworlds; such are learning environments that permit the user to decide whether the computer is to execute some function in its repertoire (whether understood by the user or not); to demonstrate its means of solving a particular problem or class of problems; or even to provide coaching and challenging problems when the user wants that guidance and testing. If we are more and more willing to relegate to machines, even conditionally, computationally burdensome algorithmic knowledge, what is left for people to know? What can be their contribution to solving problems?

People are best at recognizing problems and classifying situations (the kind of logical process that in 1878 C.S. Peirce called "abduction," (Peirce, 1998). Some might call it speculation; theory building is a fancier name. The process is one of making hypotheses to answer some question that will not go away. How can we support what is naturally strongest in human capability? It would serve people well to own a collection of valid thinkable models; thinkable models are descriptions of things and relations simple enough for use as tools for thought and as the basis of thought experiments. The following simple taxonomy attempts to relate such models to existing knowledge. (What the internal counterparts of these public models might be is a knotty question that I attempted to address in part in cognitive studies. Here we will assume merely there is something in the head reflecting the public models without specifying what it is.)

The primary characteristic of a perspective is that it defines "what's what." Since such an assertion of the applicability of a description to a thing frequently involves questions of purposes, values are often implicated in such a perspective. Consider, for example, the "argument from design" for the existence of a deity. Following the heyday of classical mechanics, theologians argued that since the universe had been shown to be a perfect clockwork mechanism, the existence of such a clock implied the existence of a clockmaker. Characteristically, the essential power for thought in a perspective is that from knowing "what's what," "what follows" is "intuitively obvious." Different perspectives lead to different conclusions on the same issue. Looking back from the Apollo spacecraft, we have seen the Earth with changed eyes. The Earth, no longer the center of the universe, is now a physical system, essentially a container for the biosphere (as noted in *Colonies in Space*, Heppenheimer, 1977). As engineers, we cannot help remarking the strange design that holds the contents on the outside of the container. (Although it would be a poor joke to say that the Earth is merely an ill-designed jar. Everything we value is near the surface, and depth in this case is less important than relations among things of the surface. From a super-terrestrial perspective, we can appreciate how important it is for an environment to permit incremental development—as in evolution and in cognition—and to be relatively well protected against the energy flux of the sun and the flotsam of star dust.)

Minimal Models go beyond perspectives to a focus on processes as well as things. These models bring together language and object-oriented descriptions of the world. They provide a repertoire of relations by which we can judge that some circumstance is of a recognizable type. Minimal models provide guidance in areas of action that are important in human concerns but beyond detailed comprehension in any thorough sense. Essentially, they provide a more or less credible cover story that asserts that specific kinds of things exist and that they interact according to some common sense scenario. P. R. Sarkar's law of social cycles is presented as such a minimal model in the once popular book *The Great Depression of 1990* (Batra, 1988). His social universe is divided into four kinds of people. Soldiers solve problems with force; intellectuals make cunning arguments; bankers accumulate wealth; and the laborers work for everyone else. The law of social cycles is as follows. Whenever the situation is a mess, soldiers seize control. Intellectuals provide justification for the soldiers' rule but eventually take over by cunning. In turn, both are then subjugated by the bankers who eventually control wealth so thoroughly that the soldiers and intellectuals are forced into the laboring class, which leads to revolutions and the seizing of power by those of soldier mentality.

Perspectives and minimal models are useful but not coercive. Such are the kinds of theories we develop when we can do no better. We use them when we must to make sense of things too important to ignore and too difficult to determine in some way that we can really count on. Both must be judged primarily by their everyday usefulness, for once the explanation or cover story is separated from the rest of the theory, there is little or nothing left.

Our world is filled with mysteries of an everyday sort. Does your average man know how his television works or what keeps airplanes from falling out of the sky? Technical and explanatory models are capable of answering such questions. Typically, the model postulates some decomposition of the domain, then in explicit fashion indicates how the behavior of the component parts interacts in such ways as to generate the observed behavior of the aggregate. Technically trained people know the Bernoulli effect permits flight and may know enough of electromagnetics, circuit theory and component design to understand how fluctuations in fields become video images. Even so, the phenomena remain mysteries to the common man; this is because they lack a simple cover story that can be related to the phenomena of everyday experience. Some theories do attain a crisp formulation that answers such objections. Such then are explanatory models.

Such explanatory models are cherished gems in physics but are not limited to the physical sciences, as can be seen in the theory of evolutionarily stable strategies, developed by J. Maynard Smith and advocated by R. Dawkins in *The Selfish Gene* (Dawkins, 1976). The theory explains why it is not always the case that the powerful and aggressive individuals dominate populations. The answer, worked out through a rigorous application of game theory, is that in any situation of conflict the best strategy, as judged by the survival of any one individual's genes, will depend on the strategies that others in the population follow. The elements of Maynard Smith's universe are conflicting individuals, a cost benefit function evaluating the outcomes of fighting (e.g., death for loss; control of a harem of brooding females for victory), and the strategies that individuals might follow (these strategies would generally be instinctual, even though they are discussed in terms of human stereotypes). This cover story serves to make the entities and the theory easier to think about.

Although thinkable models may or may not provide essential content, they do provide ideas and sometimes values useful in organizing later experiences and the knowledge constructed therefrom. Learning environment design can be seen as an effort to produce a medium of representational and functional elements in terms of which learners can develop dependable, thinkable models relevant to some specific domain. An outstanding example learning environment is the one developed by Papert and his colleagues, the turtle geometry component of the Logo programming language (Papert, 1980). The turtle is a computer controlled robot that can move and draw following commands such as pendown, forward 100 (steps) and right 90 (degrees). A central virtue claimed for turtle geometry, as implemented in Logo, was the potential for incremental learning made possible through the learner's ability to write progressively more complex procedures for controlling the robot turtle. Specifically, what learning environments add to explanatory models is an environment in which learning can develop in a natural way, an environment in which self-construction is more natural than instruction. It would be helpful if there were a systematic approach one could follow in exploring possible domains as candidates for the development of learning environments.

NR: Does this then imply a move towards access rather than curriculum?

RL: The knowledge of international science embodies what mankind has been able to understand about the nature of the world we live in, that knowledge is extensive and important. There has been an explosion of such knowledge. Once it was possible for a person with dedication and tenacity to learn all that we collectively knew. This is not longer true. What are the implications of the knowledge explosion for education objectives?

We all want our children to survive and thrive. We all want our societies to continue and be well appreciated for their unique values in the human story and history. We all claim the right to educate our heirs so they can promote the values we cherish. Institutional/cultural resolution of implicit conflicts among these aims may be less possible than in the past. That does not mean the issues are beyond resolution.

As a visiting researcher at UNESCO, I adopted their local terminology for reference to "all the stuff that everyone might possibly know." Call it the *Global Knowledge Inheritance* (GKI). What should be the relationship between any or every child in the world and that GKI? I concur in the UNESCO position that, by right, what we know should be an inheritance for all our heirs. But how can they gain access to that knowledge and how does that right sort out with the rights of family and societies to encourage their children to appreciate their cultural heritage? Consider one possible line of descent, from canonical scientific knowledge through encyclopedia like reformulations of that knowledge, and a simplifying explanatory model to games designed for access and comprehension by novices. What could the connection be like?

Generally, new learning is not a goal of most activity. Learning is most often a side effect of activities people are engaged in for some other reason. "Games" hold out the potential to engage novices in new activities with some prospective educational benefit—much as playing with the Logo turtle could engage someone with mathematical and programming ideas. Other games lead to other kinds of significant knowledge, e.g. "shooting craps" (rolling dice) could engage a novice in a grasp of probability distributions of six things taken two at a time, as well as more general notions or probabilities.

In between the child at play and the knowledge explosion, we find volunteer efforts at new constructions, such as Wikipedia and, for the literature of the past, the Gutenberg project collection.

Educators will not change human nature, but they can direct student attention to new opportunities afforded to us by the new technologies and knowledge organizations of our time. Consider

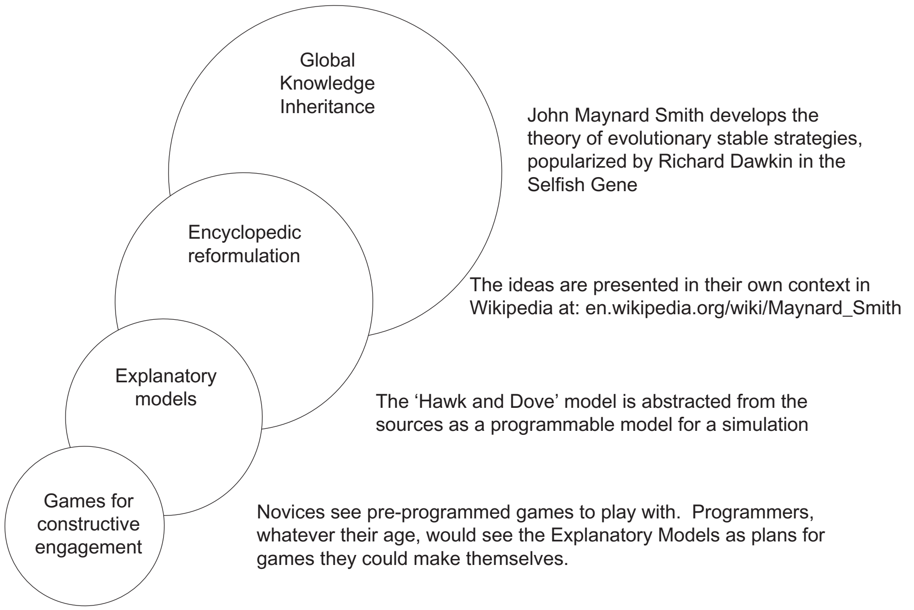

Figure 1: An example of access instead of curriculum

figure 1 as a concrete example, of how one might make a bridge between the playful novice and the GKI. Maynard Smith developed a theory focused on processes involved in evolution, the theory of evolutionarily stable strategies. It argues that social behavioral characteristics can have a determinative impact on evolution outcomes and stability. Let Maynard Smith's theory represent one example from the GKI (Figure 1). (See also Dawkins, 1976 chapter 5 for a popular presentation of these ideas.)

It would be very easy to create a Logo simulation of the primary categories of types in the model and the potential interaction outcomes based on input variables (I have done so, in a "workbench" implementation). This is where the child's enjoyment could grow into a connection with socially valued knowledge presented in an encyclopedic form, and in some cases, over time, involved engagement with the scientific community at the forefront of such knowledge. Where is the "explanatory model" in this case, between the global knowledge inheritance and the thinkable model in child's mind? It is in the design of a computer-based model that identifies the objects involved and their relationships to each other. Such models are typically implicit in things made for novices to use, but it would be most useful if they were described apart from their programmed instances. Doing that, as "documentation" would encourage teachers or other mentors of students to understand the structure and functions of the models and better enable them to connect the computer games to the ideas which the games embody. Another choice would be to prepare, in a consistent representation scheme, design documents without developing the programmed model or game. This might be done in any case; it may well be beneficial to separate the analytical specification of ideas from the artful creation on an engaging instantiation.

The effort is not merely to make a game but to make a game that some mentor can understand and relate to more extensive information in an encyclopedia-like presentation of the ideas (one would expect, at least for work with some touch of scholarship that the encyclopedic formulation would provide links into current work in the relevant field as well).

Wouldn't it be grand if we could develop entry-level games that novices would delight in, that would lead them to adopt or invent, in their minds, schemes of representations and relations among elements that would be useful in appreciating situations, recognizing problems and creating solutions to those problems. It would be especially wonderful if such facilities existed for everything we know about, so that novices—wherever they come from, whatever they are interested in—could make early, engaging, significant connection to the canonical knowledge of modern civilization—and then let their interests expand up and down the ladder of access—and across whatever areas of interest they chose.

Would it be possible to develop explanatory models for a significant portion of the knowledge of international science? My strategy in evaluating the potential for such an investigation would be first to choose some very likely test domain, such as physics as commonly taught in high school, to explore the potential breadth and depth of possible compatibility for creating games that could be linked through explanatory models to the field knowledge typically presented in courses. Second, to analyze that knowledge so that one could conceive of representations of the elements involved in the phenomena and the interrelations of those elements, seeking first the simplest cases and then more intricate refinements.

Different formulations would be differently approachable. For example, one can imagine games that depend on reflection, whether of billiard balls off cushion shots or of light reflecting off a mirror, "with the angle of incidence equal to the angle of reflection." But it is hard to imagine simply coping with Feynman's formulation of reflection as presented in *QED: The Strange Theory of Light and Matter* (Feynman, 2006), where a resultant reflection is the vector integral of all possible ways that photons can travel.

Third, to ask how one might use such phenomena in game-like re-creations that could engage people who do not at first understand what they would be dealing with. Finally to answer the question of the extent to which coverage is possible with such game micro-worlds. Such an effort would be research by analysis and invention.

Knowledge is so extensive and detailed, no one can know everything anymore. One needs to approach covering the domain of knowledge piecemeal. With the ambition to get down to ideas that work in the world, the essential question is how to find the authentic, natural organizations of information inherent in the world itself and how we learn about it. Since none of us can become the master of all knowledge at all levels of detail, an initial strategy is to adopt provisionally an organization with that end. My inclination would be to use Mortimer Adler's 10-part "outline of knowledge" in the Propædia of the *Encyclopædia Britannica* (Adler, 1974). This is a traditional choice, depending on a well considered, stable source of information. (Other choices are possible, such as the organizational structures of Wikipedia or other online knowledge presentations projects. Adler's outline would serve, at least, as root from which to begin an analysis and discussion.) It has 10 parts, 41 divisions and 167 sections. Such a research exploration would be worth examining because it could offer a general new path into the GKI, one that might supplement traditional curricula today and replace much of it in the future.

Such research would be pedagogically important because engagement with a broad range of such games would begin from what the child knows and is capable of being interested in. This would be a direct way of addressing Piaget's first requirement for understanding education in a particular case. The child's selection of what was of interest, in his zone of proximal development, would answer the question of what was in his mind. (Vygotsky, (1978) served me well in my doctoral research, as a guide to the cognitive issues where my subjects could be engaged in significant learning. Observation of the child's interactions with the games and with others, whether mentors or fellow students, would reveal what he was able to integrate into the already existing knowledge of his mind, and what knowledge required more extensive engagement and self-construction. Mentors would generally be eager to introduce "neat phenomena" to an eager learner, such as the behavior change of a backspun ping-pong ball or hula hoop, and to point out links to encyclopedic knowledge (at an appropriate level of presentation). A potentially valuable secondary benefit of such pathways to knowledge would be opening up new areas of exploration and interest to the children's mentors. For a child to see his teacher as more experienced but still learning, in an expanding universe of knowledge, would be inspiring for any student.

NR: That's all very much about the hard sciences. How about other fields of learning?

RL: Language learning and literature might seem unlikely, at first, as a choice domain for the construction of Thinkable Models. On the other hand, that could make them a good comparison with simple physics as an area to explore. Heinz Von Foerster (founder of the first AI Laboratory at the University of Illinois) used to say "The Hard Sciences appear to be hard because they tackle soft problems. The Soft Sciences face the harder problems."

I have undertaken some work in this area, so let me set out a few ideas and summarize some previous work that moves in this direction. The simplest models may be those of Papert's turtle geometry. Papert's Education ideas are well represented in his first Logo book, *Mindstorms* (Papert, 1980). The first personal computer version of the MIT Logo Project was made for the Texas Instruments TI-99 personal computer. The graphics coprocessor in that computer permitted display of 16 "sprites," computer objects with seven different state variables. I made computer-based word-worlds based on Logo sprites and used them to introduce words to very young children—my own and others in several projects (Lawler, Headstart Research Videos, 1984–1990; Lawler, Participatory Software, 1984; Lawler & Yazdani, 1992).

Humanists are happy to tell everyone how rich and complex the productions of literature are. For some works, that point can be sustained, but there are simple works too, and even simplifications of literary masterpieces (see, e.g., Lamb & Lamb, 1807). Unfortunately, too, the beauties of a complex work are beyond the reach of many who might be exposed to it: for example, in a college English class, one would be lucky to find 10% of the students sensitive to the rich textured, subtle characterization of a Henry James novel such as "The Ambassadors"). Different genres present different strengths. In contrast with the novel, drama is limited in stage time, active more than contemplative in essence, and fugitive as an art form: in the theater, one cannot replay the last 2 minutes of a live production to clarify some point important for later developments in plot. Whether one looks to plot structures as represented by Aristotle's dictum in the *Poetics* (a drama naturally breaks down to an essential structure with a beginning, middle and end) or more recent variations offered, e.g. by Grebanier in *Playwriting*: or to character, simplifications are possible that permit the better understanding of role interactions and their interplay with story development and literary meaning. For these reason, I would nominate drama as an area to explore for developing Thinkable Models. It is possible to make Logo-like facilities enabling young people to compose their own little dramatic skits. As an existence proof only and not as an advertisement, years ago, I developed an LCSI Microworld EX Logo Project, "Directing Animation Theater." Demos are accessible but too fragile to release publicly.

The opportunities for useful, creative research are greater now than they have ever been. The possibility of helping people learn through computing and networks can bring the GKI within the reach of billions of people—if there is the will, the energy, the creativity and the perceived value for making it happen. What a wonderful time!

NR: You said that you had three heroes. Who is the third?

RL: My third hero is Oliver Gordon Selfridge. Minsky sent me to work with Oliver in 1984. We became good friends and colleagues for many years, for we shared a profound interest in Artificial Intelligence and many other fields as well, even including poetry. Selfridge's signature mature paper was The Gardens of Learning: a vision for AI (*Selfridge, 1993*). Authentic and incomparable, Oliver the man, studied with Norbert Wiener, and inspired Walter Pitts, Jerome

Lettvin and Ulrich Neisser in their seminal works. Selfridge and Minsky together managed project MAC (Machine Aided Cognition) before the advent of Artificial Intelligence!

Oliver recalled to my mind some lines by Robert Frost that were central to his life as they are to mine. I recommend them to you:

My object in living is to unite
My avocation and my vocation,
As my two eyes make one in sight.
Only when love and need are one,
And work is play for mortal stakes
Is the deed every truly done
For Heaven's and the Future's sakes.
(Frost, 1949)

As friends do, Oliver and I had some disagreements. I once made a dismissive reference to an earlier era as "those days when giants walked the earth." Oliver called me up short. "Do not be disrespectful, Bob," he admonished. "There were such days. There were giants walking the earth. There still are giants, but something has changed. You have grown up and you are now one of us . . . and we are so grateful to have you working with us."

My generous friend sketched a personal view of the promising future. My message to the researchers of today is: Such is your destiny and obligation. You will be giants, and we are so glad to have you working with us on the challenges of our time.

NR: Bob, you said that you are now working on your retirement project. What are you doing exactly?

RL: I have long advocated Case Study as the method of choice for exploring how everyday knowledge is built in the mind from the processes of natural learning. But for many serious scholars and researchers, case study is suspect, for a variety of reasons. My goal in retirement is to render case study more credible as a method, while at the same time integrating the corpora and analyses I have developed since I first joined Minsky and Papert at MIT. That work is going forward on my website called the Natural Learning Case Study Archive, and you can find it at http:NLCSA.net

THAT is where my love and need are one . . . . someone asked me recently what should go on my tombstone. The answer?

If you don't find me lurking around here, try Google. I'm emigrating to the internet!

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