About the Intelligence of Artificial Education

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There are many who predict that the computer will never rise to more important roles in education than those of simulator and drill-and-practice machine and

others (e.g., textprocessor), which it fulfills at home too. And many computers will gather cobwebs, thus speak the Cassandras. Indeed, one of the major scientific challenges of our time is how to make computers perform more interesting tasks, in education and elsewhere. I choose the word "interesting" instead of "intelligent" to sidestep a debate on the true nature of intelligence. That is, in my view, something to find out empirically, while what is interesting is a free decision each generation has to make for itself. For the contributors to this volume, the decision is clear. What we want is computers both as presenting challenging learning environments and as intelligent tutoring systems. The organization of this collection of papers reflects the distinction that is still to be made between these two roles of the computer in education. The first part consists of nine chapters, which are concerned with the computer as a means to let the student explore, discover, and master the regularities of a lawful, so-called microworld. The second part also contains nine chapters, which are written from the perspective of using computers as an intelligent tutoring system (ITS). Each part starts with a chapter, by Lawler and Yazdani, respectively, giving an overview of the history, the basic philosophy, and the current developments within its theoretical stream. The remaining chapters in each half are ordered from the more general and theoretical to the more specific and technical. An introduction by the editors caps both halves, pointing to ways in which the best of the two approaches to interesting uses of computers in education may be fused. The conference on which this book is based (2nd Conference on AI and Education) must have been exceptionally well organized for so balanced an organization, on so high a level, to be possible.

A well-balanced and transparent organization makes things considerably easier for the critic. What is obscured one cannot knock! What I want to criticize in this excellent (let me be very clear about this) volume of papers is actually the neat balance, bordering on a compartmentalization, of the microworld papers and the papers on ITS. In the actual research on AI and education, the forces are far from being divided 50% on microworlds and 50% on ITS. Let me put it in the way of Cassandra: In the second volume of this series, hopefully to appear this or the following year, this strict 50–50 apportioning will not be attempted again. Already several chapters in the microworld-half of the present volume point that way, specifically Feurzeig's discussion in Chapter 2 of "intelligent microworlds." The attractions of the possibilities offered by the AI and knowledge engineering techniques, used more and more by the ITS community, will (that is my prophecy) prove to be irresistible. But there is more.

The first time this reviewer came across LOGO was in a paper by Feurzeig and Papert (1969) presented (by Glaser) at an international conference on programmed learning research. This conference, by the way, was held in May 1968, in Nice, in the very days when France was shaken by demands for imagination to come to power. The edited proceedings of this conference read as a remote but direct ancestor of the volume we are reviewing. The dominant psychology in Computer Assisted Instruction (CAI) research of that time was behavioristic: Reinforcement, generalization, and inhibition—all of various kinds—held sway. Of representatives of what now is called cognitive psychology, there were less than a handful, and Piaget was only mentioned once, critically. In this climate the notion that the (for many, unsurmountable) gap between intuitive understanding and formal scientific thought can be bridged and that this can be done by having students learn to write programs by experience and experiment in a mathematical laboratory came as a refreshing breeze. All this in the terminology of 1968. The LOGO turtle microworld came later, as did the elaboration of the parallels of thinking with Piaget. Refreshing was the break with the then dominant law of instruction that said that any response can be firmly installed in a student's response repertoire by first drawing it out and then reinforcing it. Science and mathematics educators knew better all the time. Equally welcome was the notion of the student as the one ultimately responsible for creating his or her understanding of the world, and of education as being the presenting of an adequate and playful ecology for the knowledge generating activities of the student. It is not my aim to sketch the history of the LOGO movement since the late 1960s. Suffice it to say that it indeed has grown into a real capital letter movement, and I am wary of movements. Therefore, I will welcome the assimilation of what is still attractive in the microworld tradition into the mainstream of ITS research. What is it that I am wary of and critical about in this instance? Movements have founding fathers, crown princes, jealously guarded basic tenets (difficult to understand for nonbelievers), original experiences, and internal and external enemies to be combated with revolutionary fervor. Much of this can be found in the LOGO community. It leads demonstrably to intellectual insularity. The sense of being on a crusade was, in my view, the reason that LOGOism failed to connect with the cognitive psychological approach that so rapidly became the mainstream of psychological theorizing and research; it failed even to connect with modern developments in Piagetian theorizing. This left the microworld approach without a good theoretical basis (remember that Piaget does not provide a psychology), a prerequisite for further growth. Also, it put a serious constraint on the ability of the group to do something with and learn from the many negative results of empirical outcome-research concerning the LOGO approach to education. To say now, after 20 years, that the type of learning you are after is too subtle to be easily measured just does not do. Programmed Instruction (PI) in the 1960s did have a serious theoretical grounding in Skinner's behavioral theory. It was not only the boredom of students that doomed PI but, more important, the fact that this theory was proved, by empirical test, not to be able to explain what happened and did not happen in PI. From this kind of openness comes growth (e.g., CAI sought and found a new theoretical basis in cognitive instructional psychology and from that the link to AI, both the theory and the techniques, came naturally). So LOGO's traditional enemy, mechanized and mechanistic instruction, proved itself capable of learning—much more so than the members of the LOGO movement.

One would have wanted to see all of this discussed in the LOGO part of this book. It contains excellent chapters, specifically the first five (Lawler; Feurzeig; diSessa; Papert; and the Lawlers). I applaud their depth of thinking, their command of the language, and their enthusiasm, but I feel as if I am listening to a prophet some weeks after the doomsday that did not come.

And now for the second half! In the 1970s the problems of AI (and ITS) were simple: Hardware of sufficient capacity was not available, machines that accepted LISP and other such languages were scarce, and adequate training facilities for students did not exist. Generally speaking, this phase is over. Now ITS is facing its authentic problems (and let us hope that those of the microworlds will join forces trying to solve them!). A first problem is how interesting (intelligent) an in-

telligent tutorial system still can be if we give up natural language communication as an insoluble problem. Second is the problem of how to come by the teaching strategies and teaching tactics an ITS needs and that many naively thought could be found in some handbook of teaching, which, however, proved not to exist. A third problem concerns diagnosis. Intelligent tutoring means "moment-by-moment adaption of instructional content and form to the changing cognitive needs of the individual learner" (p. 204). This goal points to the need for on-line cognitive diagnosis. But, even granted natural language communication, how do you diagnose the naive, ill-formed conceptions (possibly endless in variety) of beginning learners? How to represent formally (a necessity for a computer) the ill-formed?

Theoretical questions such as these are central concerns of present-day CAI. They, and several others just as searching, are treated in great depth in several excellent chapters, specifically in "Some Principles of Intelligent Tutoring" by Ohlsson, which has the makings of a classic. Other chapters, also very well done, treat recent developments in the field on a more technical level.

Overall, I think this volume presents a happy start for a series that may well turn out to be the trendsetter and the binding element for the expanding flow of papers and reports in the field of ITS. It is of obvious interest to anybody already involved in ITS. And to many others; specifically those who, with this reviewer, believe that, even when it will still take many years to get to the classroom level, educational psychology will greatly profit from our efforts to get there. Realizing the goals of interesting computational instruction forces psychology to be explicit, detailed, and specific about its subject matter to a degree that will leave its marks far outside ITS proper. There is much evidence in this volume that supports this thesis.

Reference

Feurzeig, W., & Papert, S. (1969). Programming languages as a conceptual framework for teaching mathematics. In F. Bresson (Ed.), *Programmed learning research, Major trends* (pp. 233–248). Paris: Dunod.