domain information at various levels of sophistication and in various schemes of representation. Such cells can include alternative theories as well as multiple representations of the specific knowledge. Hypertext database organization should support in a natural fashion cross-representational correspondence links at the most detailed levels of the various models.

This is very general, in terms of the broad differences among systems of representation. But if you imagine that a real good for an individual is to have a mind which has a multitude of ways of viewing any particular situation, so that flexibility is a natural consequence of the human mind's abductive power, this focus on multiple descriptions applicable to common situations is a key to what it means for people to have effective and flexible minds.

Oliver Returning to the pyramidal access scheme to your multifaceted encyclopedia, I'm sure you realize how much thought and effort will be required to develop such a scheme to a point where its utility would be obvious and its worth determinable. Even if you could, in a pilot version of such a system, solve some of the technical problems of knowledge access for student-centered education, it doesn't help us approach values and how they relate to purposes.

MOTIVATION OF THE INDIVIDUAL

Oliver Let's assume, for discussion's sake, that such a view is worth advancing. Now let's ask how it relates to values and the should questions of education. My first criticism is that your proposal for a curriculum of neat ideas is focused on the "should" of the teacher, not that of the student. What do you think of the "should" of the student? What and where do you think interest comes from?

Bob Carl Rogers spoke on campus during my student days at Cal Tech. He described (1961) the process of natural growth with a phrase from Kierkegaard, as reflecting the effort of each individual to become that person which he most essentially is. He saw people as trying to bring their lives into some sort of coherent registration with the people they either perceived themselves to be or hoped that they would be someday. For young people, adolescents especially, I imagine that remains an abiding motivation.

Oliver I respect such objectives, even though I consider the expression too general to be very helpful. Let's take your example of Cantor's proof

as a test case for these issues. The possibility of explaining that proof, of talking about it effectively for the students, is going to occur in most educational systems late enough (typically 13 or 14) that people will have begun to make choices about their own talents and capabilities and interests. Now remember that you can't do the diagonal theorem without substantial sophistication to begin with—and sophistication of a mathematical kind. There are very many bright adults you just couldn't hope to get the idea across to. They wouldn't know what it means, they wouldn't begin to accept the concept of denumerability in the first place. And even saying that one understands and accepts some theorem does not, of course, mean much, because understanding is more than knowing the theorem, it's rooted in familiarity. Now, to get familiar enough with numbers to be able to use them as friends, and with the notion of sets, and then with the notion of denumerability, just to begin to have access to notions of infinity at all, that is where you must begin in order to say that Cantor's theorem has beauty. And you've got to build up to that point through ways which, in our culture, most people don't have.

By the age people can understand Cantor's Proof, many will decide they don't care to. There are large numbers of beautiful things like that, items that will be of intense interest to only a few. There may be some hope of engaging people with this bit of arcana, but only because Cantor's proof goes beyond mathematical beauty.

Bob What do you mean?

Oliver The subject of the proof is something which is entrancing for most people anyhow, concepts and ideas of infinity, which go very deeply, so to speak. Mankind has been distinguished from other creatures as the first animal who has a concept of eternity. Where does mankind fit in infinity, in eternity? I think this question has been an incredible though subterranean driving force for nearly all the aspects of civilization. Our cultures try to make a cosmos out of chaos—to fit man into infinity—this fragile person, who is bounded in everything except his imagination.

Bob Who can "See the World in a grain of sand All Heaven in a wild flower, Hold Infinity in the palm of his hand And Eternity in an hour."

Oliver And in Blake's sense exactly, one can justify the study of Cantor's proof as—I'm trying to support you—as one nifty way to get a grip on infinity, some familiarity and control. Because once you know something, familiarity is a kind of control. At least it enables a kind of control, for very hard things, well, get handleable by familiarity. Even

though I understand and sympathize with your objective, I'm not so hopeful as you are. You know, for example, neither Picasso nor Admiral Nimitz would have cared about Cantor's proof. Now they weren't stupid people. It's not clear that their sense of beauty or duty would have begun to include any such very arcane ideas. What is the difference between your motivation and theirs?

FAMILIARITY AND THE SURFACING OF QUESTIONS

Oliver Learning involves having questions in mind, specifically in the mind of the learner. In this sense, the surfacing of a question is a precursor of motivation. Here's an example. I was putting a dimmer switch in the dining room light circuit. A friend of mind said, "Don't touch that, Oliver, I'll go down the cellar and turn off the electricity." So I said, "Look, I know about these things; I've got my tools, I haven't been electrocuted yet and I'm not going to be. In any case, I've been to MIT, I know about these things." So she reluctantly sat and watched. I took the wires out and took off the old switch and the lights went out. I put the two wires together in my hand and the lights went on. And she said, "Oh, is that all a light switch does?" She's very smart, but she had never formulated what a light switch does—it had never occurred to her that the light switch in effect joins two wires together and lets the current flow.

Bob It wasn't that she had a wrong idea.

Oliver If such questions don't arise, you can't have notions of beauty in them or not. Beauty is with respect to experience, and that means with respect to familiarity. It's hard for me, as a mathematician, to think that Picasso's or Jackson Pollock's work is beautiful. I have so little familiarity with them. You don't come in as a *tabula rasa* and see beauty. Beauty arises after familiarity.

FAMILIARITY AND REPAIRING MISCONCEPTIONS

Oliver Familiarity is most important. It's a vastly underrated catalyst. It is essential for thinking clearly enough to surmount misconceptions. Another example: My second term as a freshman, we were using determinants to solve systems of linear equations.

Bob It's been a while for me too, but I follow.

Oliver All the exercises that you do in determinants have order two or three, because it's just too much computation otherwise. Well you can do order two and order three determinants very easily by subtracting the downward left-going diagonals from the downward right-going diagonals to get its value. I had no trouble with determinants until the final exam, where I was baffled with a determinant of order four. Then I realized that knowing how to use determinants wasn't enough. My easily construct was just plain wrong. Later, because the familiarity was there, however, I said, "Oh, that's all it is; I've got to change that." It wasn't the case that I had to redo everything from the beginning. I knew how to use determinants just fine in solving linear equations, which is what we used them form, it's just that I had learned the wrong thing. In permitting a simple correction to my mistaken ideas, the important thing was the familiarity.

SCHOOLS AS LACKING PURPOSES

Bob One of your long-term themes has been the centrality of purpose in intelligent action—whether in machines or people. I suppose that purpose must be a central notion for educational organizations as well. A friend of ours in Paris started his own school. One of his notions was that the problem with schools is their lack of functions or purposes that go to the world outside. They're all organizations that operate upon components of themselves and in that sense they are extremely introverted and destructive. My friend's intention was that as the children in his school got beyond the elementary grades they should undertake activities that would put them in direct operation in the world at large. For example, they might begin a newspaper that would be of use to other people in the city, and then go around and try to sell it, and become actively engaged in doing something that related to the world outside. Well the point is, is it possible to imagine that schools might have purposes?

Oliver Well, I hope so. They do in fact. The question is, is there some set of implicit or perceived purposes which may even be somewhat more than those professed and practiced by the faculty or students. I came from England to Middlesex, a boys' prep school in Concord, Massachusetts, the year before going to MIT. It happened that half a dozen boys had intellectual bents. They were interested in ideas and were scholastically very good. They were also stars in sports as well. Middlesex had then always had a reputation of being something of a jock school, but these particular kids established a tradition, which lasted for a decade or so, of treasuring the intellectual subjects. What kept that tradition going, I don't know. But it was more intellectually

effective than the professed values of the teachers, who didn't affect the school nearly as much as those few bright kids.

Bob I don't know where your example leads me.

Oliver We have difficulties because we want to simplify purposes and make them into simple rules about satisficing things. One might ask what was the purpose of some course. Well, it's not appropriate to say I've got to pass this course to get a good grade so I can do something else. The notion of using what is learned or being able to do something with it, whether to get wiser, or to travel abroad, or to do better at a job, never really occurs to many students. Many want to simplify things so they don't have to think about the relations and complexities of real life, which they do in every other part of their existence. I suppose we ought to want education to be—I hate to use these words—richly tied in with all the other things the students are experiencing, because that's really what it's about, to get better ways for describing and articulating how complicated things interact. The motivations in an educational system are as broad as the motivations in society. One doesn't or shouldn't get educated for a single reason or a single cluster of reasons. You get educated to be educated, to be able to do well as a citizen, to be able to pass on learning to children, to be able to have a job, to open one's options, to maintain one's flexibility. Given all that, then one chooses, either wisely or foolishly, the particular kinds of education one is going to pursue later—as one gets older and wiser one gets to be able to choose at a deeper level.

CONFLICTING PURPOSES

Oliver One of the hardest things to know is how to handle conflicting purposes, how you want two things at once, accepting that they may be opposed to each other. Psychiatrists vacation in the Caribbean because people have a tough time realizing they can love and hate the same person at the same time. We don't have good terminologies for relationships, so we can't really communicate what we do know about such issues. Part of education in the broad sense has to be expanding capabilities for dealing with people and their capabilities to communicate—which is, of course, very culture dependent.

But I mean something a little more than communicating mere words. How do we enable our growing people, that includes all of us, to make appropriate models of what other people are? The only really effective way to deal with other people is to understand what they're after, and yet most children don't, and most grownups don't either. One of the hardest things to teach a child is to think about what some other child

wants, so that the child can, by manipulating the model, put himself outside of himself. Most parents don't discuss the desirability of doing this, developing knowledge that enables the child to exercise control. Now I don't mean control as directive, as in driving a car; I mean to interact in useful and appropriate ways, which is what control is. But whenever the notion is brought up, control is represented as hierarchical and manipulative—

Bob It need not only be that.

Oliver Exactly. What I mean by control is sort of appropriate interactions for the common or separate purposes and to give that notion some substance you have to have models. You and I have common backgrounds and common interests, so my model of you doesn't have to be modified very much as I get to know you better. I understand the kinds of things you value. We can't talk about that to most kids, so how do we help them do it? If it's done at all, the kid does it by guess and by god and not very well. And some kids do relate well, by their own innate pressures, but I would like to see them as able to talk about that.

Modeling people's goals depends on recognizing feelings in others. Since we don't talk about it, we certainly can't measure it. And yet I think we all feel that it provides a class of capabilities which ought to be constructive and helpful and appropriate for people. This is a side of education which is hardly discussed at all. One wants one's children to have models of people which work—and also the metamodel to show how much people can differ from stereotypes. Fundamentally, what's hard about all this is we have no good way of talking about it.

Bob Well, it would be clearly of value for children to be able to recognize the appropriateness of a sort of co-recursion of invocation as a model of cooperative communication versus hierarchical invocation—to be able to distinguish between the times they're interacting with shared initiatives and when they're being very directly manipulated by somebody.

Oliver Exactly so in a technical sense, but do you know any children who would understand what you've just said? To be able to recognize feelings in others would be the direct, human way of developing the familiarity that might permit, ultimately, a more sophisticated expression and understanding of human interactions.

SOCIETY'S PROBLEMS

Bob Suppose developing that were a specific item on your agenda for change, how would you move if you were in a position to have