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Questions and Answers about Radical Constructivism

Introductory Remark

The questions I try to answer in the pages that follow were raised after talks I gave at the NARST Meeting in Atlanta (April 1990) and at an AAAS Symposium in Washington (February 1991). Given the limitation of time at both occasions, I could deal only with a small selection. Reviewing the whole collection at a later date, I found that it could be roughly divided into three subject areas and this is how I have arranged them here. I begin with the specifically epistemological ones, then take those that concern the problem of social interaction, and end with some implications the constructivist orientation might have for teachers and the philosophy of instruction. Since the answers I give are not derived from an established dogma but spring from my subjective point of view, the reader will find a certain amount of overlap between the three sections. I like to claim that this is inevitable because, in my experience, once one shifts to the constructivist orientation, everything one thinks and does changes in a way that seems remarkably similar and coherent. But let me emphasize a point I have made in many of my papers: Constructivism, as far as I am concerned, is *one* possible way of thinking. It is a *model*—and models, no matter how useful they might prove, must never be claimed to be "true."

Epistemology

(A14) Is C. primarily an epistemology or a pedagogy?

Constructivism deals with questions of knowledge—what knowledge is and where it comes from. It can therefore be considered an exercise in epistemology. The idea that knowledge is constructed by the knower is as old as Western philosophy. The Pre-Socratics in the 6th and 5th century B.C. were already aware of the fact that not everything they knew could be said to come from sensation and that the mind, the specifically human mind, was to a large extent responsible for shaping human knowledge. Some of them also noticed that there was a serious problem about the claim that knowledge could and should faithfully reflect a world held to be independent of the knower. They had realised that there is no way of checking

knowledge against what it was supposed to represent. One can compare knowledge only with other knowledge. The later sceptics have never tired of reiterating this irrefutable argument.

Recently, the reviewer of a paper of mine said that constructivism was "post-epistemological," and she was quite right (Nel Noddings in *Constructivist views on the teaching and learning of mathematics*, JRME Monograph #4, edited by Bob Davis, Carolyn Maher & Nel Noddings, NCTM, 1990). Indeed, the constructivist theory does not fit into the conceptual patterns of traditional epistemology, precisely because it posits a different relation between knowledge and that "real" outside world. Because it changes that important relation, I prefer to call it a *theory of knowing* rather than a theory of knowledge. (Please note that constructivism does not *deny* an outside world; it merely [...]

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"Social constructionism" is a recent development, started by some who claim radical C. does not take into account the role of social interaction in the construction of knowledge. The claim, as I see it, is partly justified by the fact that neither Piaget nor any more recent constructivist has actually specified a detailed model of how social interaction works from the C. point of view. On the other hand, Piaget and all of us who have derived our impetus from him, have always maintained that social interaction is a powerful influence in the construction of knowledge. But we were busy devising models for all the elementary constructing that has to be done before a cognitive organism can begin to know and interact with others. As far as I know, the social constructionists tend to take society as a given, and a radical constructivist cannot accept this. From my point of view, "society" must be analysed as a conceptual construct, before its role in the further construction of concepts can be explained and properly assessed.

(A28) What are the differences between C. and idealism? Is the distinction a qualitative one?

Idealism holds that the mind and its constructs are the only reality. C. holds that we can know only what our minds construct, but that its constructing is not free (ad lib): just as some ways of acting "work" and others do not, so some of our conceptual constructs and theories work and others do not. For C., the fact that something works (is "viable") does not mean that it therefore is a representation of that "real" world that prevents other things from working. The "real" world remains unknowable no matter how well we manage in the domain of our experience. (This, by the way, also differentiates C. from pragmatism with which it has much in common.)

(A38) Was Descartes revealing his constructivist view when he said "I think therefore I am?"

Descartes was a very complex thinker and not averse to the notion of construction. Analytic geometry, one of his major achievements, is an explicit example of cognitive construction. But I would not interpret his famous "cogito" phrase as a constructivist statement about the self. The mind was very much an ontological given for D. He called it *res cogitans* (the thinking thing) and he saw it as an entity separate from a

world that exists in its own right (*res extensa*) and about which the knower can find out some things, not through the senses but by logical reasoning.

(W8) What is the role of truth in your model?

Constructivism is an attempt to cut loose from the philosophical tradition and specifically from the philosophical tradition that knowledge has to be a representation of reality. Where reality is spelled with a capital and what is meant by it is a world prior to having been experienced. Truth in constructivism, as I keep repeating, is replaced by *viability.* That is a stark step to take. I've given many philosophical arguments (or excuses, if you will) for taking this step in a number of papers. Here let me just mention one thing, because it seems the most important in this context. If we want to talk in terms of "Truth" and mean by this that what we say and what we think should be a replica of the world *as it is,* we have to believe that we can visualize or imagine what that "real" world is like. We have to conceive of that world in terms of existence in the sense that it exists by itself prior to our noticing, perceiving, and thinking about it. Now, I claim that we cannot put any meaning to the expression "to exist" *outside our sphere of experience*. To us, "to exist" means by and large to have a location in space and in time. But if space and time, as Kant said, are forms of our experiencing and do not actually belong to the ontological reality beyond our experience, we have no way of visualizing things without space and time. And for me that is a good reason for giving up the notion that we have to know or imagine what the world is like before we experience it. Rather we must try to develop a theory that provides a relatively coherent explanation for how we come to have the kind of knowledge we use in our living.

(A2) Is knowledge something to be presented to a learner or is it an activity?

Knowledge is always the result of a constructive activity and, therefore, it cannot be transferred to a passive receiver. It has to be actively built up by every single knower. A teacher, however, can orient a learner in a general direction, and constraints can be set up that prevent the learner from constructing in directions that seem unsuitable to the teacher.

(A4) Does the fact that we can predict physical phenomena with a great deal of accuracy not mean that the picture of reality we have constructed is congruent with the 'real' world outside?

No. This question goes to a key element of C. Predictions we make, whether we are physicists or ordinary human beings, predict experiences, that is to say things we perceive, feel, and think. What we perceive, feel, and think is necessarily the result of our ways and means of carrying out these activities. The results can never be said to be like, let alone "congruent," with an ontological reality; all we may conclude is that this "real world" *allows* us to perceive and think certain things. If a prediction turns out to be right, a C. can only say that the knowledge from which the prediction was derived, proved viable under the particular circumstances of the case.

(A34) Some concepts seem to be based on a physical stimulus, e.g., "chair." Others seem more abstract, e.g., "I.Q." Is there a continuum from those triggered by some external stimulus to those that are more abstract?

When we say "physical stimulus," we say more than we know. All we actually know, is that we have had, or are having, a perceptual or, as Piaget would say, a sensory-motor experience (see preceding answer). To conclude that, because we have a perceptual experience which we call "chair," there must be a chair in the "real" world, is to commit the realist fallacy. We have no way of knowing what is or could be beyond our experiential interface. If we can reliably repeat the chair-experience, we can only conclude that, under the particular circumstances, it is a viable construct.

Something like "I.Q." is not a sensory-motor experience but, like any measurement, the result of a number of abstractions. In Piaget's terms, it would be an "operative" concept, because it is derived from operations we have to carry out. The terms "concrete" and "abstract" are not useful in C., because conceptual analysis shows that there are many levels of abstraction. The first level would be abstraction from sensory-motor experiences. Once such an abstraction has been made, its result can immediately be taken as material for a further abstraction, and so on. Thus, there is a continuum of levels of abstraction.

(A39) Are there physical scientists who disagree with C.? If so, name one or two and indicate where they disagree with what you have said.

Among the great physicists, most have said and written things that imply a constructivist position. Nearly all these statements were anticipated by Hermann von Helmholtz, who wrote in 1881: "The principle of causality is in fact nothing but the presupposition of the law-likeness of all of the appearances of nature" (von Helmholtz, *Epistemological writings*, Dordrecht: Reidel, 1977; p.180). I feel, however, that contemporary physicists are in tacit agreement with Popper, who admits that the sceptics' arguments are irrefutable and that an "instrumentalist" view of knowledge is quite reasonable, but goes on to say that it is better for scientists to continue to believe that they are getting closer to understanding the "real" world. Needless to say, I do not share this double standard.

From the limited experience I have had in the last few years with physics instruction, I would say that most physics teachers have little sympathy for C. They prefer to talk as though they were describing an absolute reality. If pushed a little, they may say "Well, of course, we don't know for sure," or "students don't like uncertainty, they want to know how things really are."

(A17) Is there a concept of progress in radical C., or no change, or is all change random?

Constructivists would be rather foolish to deny that we know more today than did, say, the Pre-Socratics or even Newton. But the growth of knowledge concerns knowledge of how to do things. The fact that we can "send a man to the moon" and can have a phone conversation from our moving car, does not mean that the conceptual structures and action programs we have developed are any more a representation of ontological reality. We have learned a great deal about how to set up and manage useful regularities in our experiential world. We know many more things

the world allows us to do. We have, after all, learned even how to demolish our experiential world irrevocably. But for C. it is an illusion to believe that what we can do gives a picture of the "real" world. It describes our experiential reality as we happen to be experiencing it. And what we experience is necessarily shaped and co-ordinated according to the concepts and conceptual relations we are using at the moment.

(A29) Is truth then an act of faith?

Yes. C. does not deal with the traditional conception of "Truth," which would require that one knows, or at least believes, that an idea, a theory, or any conceptual construct is an accurate representation or duplication of something beyond our experiential field. Truth in that sense may be felt (perhaps acquired) by following the mystics, but it is not a *rational* procedure that leads to it. Note that I am in no way disparaging or discounting what the mystics tell us—I am merely saying don't try to explain it rationally.

C. replaces the notion of truth with that of viability, which does not refer to anything outside the experiential field. This is analogous to pragmatism; but pragmatists formulated the slogan "true is what works," and their use of the word "true" is, to my mind, misleading.

(A22) If we cannot know reality, can we understand, test, and evaluate others' constructed realities? How can we test another's scientific hypothesis and have valid grounds for rejecting or accepting it?

Scientific hypotheses are "tested" in the experiential world where they either do or do not what they are claimed to do. Experiential worlds belong to individuals, but in the course of social interaction these individual worlds become adapted to one another and come to form a *consensual domain*, i.e. an area where the interactors' mutual expectations are more or less regularly realized (see section on the "social"). The consensual domain of the scientific subculture, because of its many specific constraints, is particularly homogeneous and new hypotheses are "tested" against that (relatively) homogeneous background. If the new hypothesis makes too many new assumptions, it will usually be discarded regardless of whether it works or not (e.g. Wegener's hypothesis of "continental drift," proposed at a time when the notion of floating continents was considered preposterous by the entire scientific community. It took a lot of new experiential "evidence" to become acceptable.)

(A15) Does reality exist aside from one's construction of reality? How do you know?

I don't. As far as logic is concerned, I could be one of Leibniz' monads, i.e. a closed, impermeable entity whose "experience" is like a movie that automatically runs its preordained course. But this is not a particularly useful model. I prefer the model built on the notion of viability within the space left free between constraints whose origin I can never tell.

The main difficulty of the question arises from the word "exist." In our human usage, it means to have some location in space, time, or both. But since space and time are our experiential constructs, the word "to exist" has no meaning outside the field of our experience, and whatever an independent ontological reality may do, it is not something we can visualize or understand.

(A10) Shouldn't there be a new label for reality as it exists, to distinguish it from subjective reality?

Yes. But a label is not much use if one can never demonstrate what it stands for. I try to say "experiential reality" as often as I can and, in contrast, put that other mystical "reality" in quotation marks (see Q29). In German there are two convenient words, "*Wirklichkeit*" the reality due to one's actions, and "*Realität*" which can be used for the other.

(A21) What harm is there in remaining a realist? What do I have to gain by thinking as a radical constructivist?

No harm at all, as long as you don't tell others that the reality you have constructed is the one they ought to, or worse, must believe in. In everyday interactions, we all go on as though our experiential reality were the same obligatory reality for everyone. But if one gets into psychology or education, taking account of the subjective nature of experiential realities becomes a matter of honesty.

(A9) How does C. escape the 'hermeneutic circle': "Is C. an adequate view of knowledge and the world despite the fact that all knowledge is held to be relative?"

Hermeneutics searches for the "true" interpretation, constructivism does not. Constructivism is deliberately circular and never claims "objectivity." We cannot look at our experiential worlds from the outside. We construct them from the inside and have usually lived a good many years in them, before we begin to wonder where they came from and what they "really" are. It would be more than a little presumptuous to believe that we could "know" the world that has produced us and our ways and means of thinking. It would require what Hilary Putnam has called "the God's-eye view." In contrast, we can always decide whether a way of acting or thinking is "adequate," because it either does what we expect of it, or it does not.

(A11) Is C. a belief?

If you call it "belief" when one has constructed a model and finds it the most adequate one has so far developed, then I would say yes. But it is certainly not belief in an absolute "truth" or revelation. To me, it simply seems to be the most viable view at the moment.

(A12) You alluded to the existence of an all-knowing 'real' God. How can you reconcile the belief in C. with the belief in a real God?

"Alluding to God" is not the same as believing in one. Vico, the first explicit constructivist, said "A human being can know only what humans have made, God can know the world because He created it." This is not even an hypothesis but merely a conjecture—it might be the case and it might not be the case. A mystic may "know," but that knowledge would not be rational knowledge. This is not a statement of value but a statement of methodology. I have the greatest respect for mystics although I know nothing about how they operate.

(A6) How do you hold up C. for scrutiny?

By letting people see whether it works, where "to work" means to be as consistent as possible and to cover as much ground as possible. The assessment has to be in terms of *viability* not in terms of "truth."

(A13) Is realism typically a Western philosophy? If so, would you say something about Eastern philosophy.

Our textbooks and television (even NOVA programs) are all too often manifestations of *Scientism*, a pseudo-philosophy that I would call the most recent Western religion precisely because it claims to have found objective "truth." The realism the scientistic religion entails is certainly characteristic of the West.

The little I have learned about Eastern philosophy does not make me competent to answer the second part of the question. I have the impression that Buddhism and Taoism tend to take rational knowledge and commonsense reality less seriously than we do, and the teaching of Zen seems to aim precisely at weaning the student from the frantic attachment to naive realism.

Role of the Social

(A16) How does C. view a body of common knowledge, such as in a textbook or field?

It is an illusion that there is knowledge in textbooks or documents. They contain language, that is strings of words, put into them by authors. The words have meaning for both the authors and the readers and interpreters, each one of whom has built up his or her subjective meanings according to his or her individual experience. Though these individual meanings are constructs that have been through a certain amount of social adaptation (because their users have socially interacted with others), they remain subjective and to some extent idiosyncratic—which never fails to come to the surface in a serious discussion. Texts *contain* neither meaning or knowledge—they are a scaffolding on which readers can build their interpretation (see Q3, below).

(W5) Where and how is language taught?

I would say that the foundation of language is not taught at all. Children learn that by themselves. You can't teach language to a two-year old or a three-year old. You may occasionally be able to show them the use of a new word, but even this often does not work too well. Later, specific interaction can focus on specific linguistic difficulties. That is why teaching language at a later stage—by correcting what children say—is enormously important. Unfortunately this seems to have gone by the board, because parents no longer have many extensive *conversations* with their children. Conversation has been replaced by television, and television, being a money-making enterprise keyed to the lowest levels of literacy, rarely provides a model for good language.

But then, you might say, a lot of language can be learned from dictionaries. Dictionaries, however, contain definitions that are simply other words, they do not provide the experience from which meanings are abstracted. They do not give us *new* cognitive elements, but only new combinations of elements that we already possess.

In general, language is learned in the course of interaction with other speakers, because speaking *is* a form of interacting, and we modify our use of words and utterances when they do not yield the expected results. Insofar as a classroom is interactive it contributes to the students' linguistic development and also provides them with opportunities to witness the use of words in the context of the experiences to which they refer. That is why it is so very important to provide to students the experiences about which they are to learn.

(A3) What is the role of 'social instruction?'

I take it this refers to "group learning," and there is a lot to be said about this.

(1) Students who work at a problem together with other students have to verbalize how they see the problem and what they want to do about it. This is one way of generating reflection, which requires awareness of what one is thinking and doing. This, in turn, provides occasions for active abstraction (repeating, writing down, and learning by heart what a teacher says, does none of this).

(2) Explaining something to a peer usually leads to seeing things more clearly and often to spotting inconsistencies in one's own thoughts. And when a small group explains its "solution" (irrespective of whether it happens to be viable or not) to the whole class, this provides a wonderful opportunity for learning (cf. the work of Paul Cobb, Ken Tobin, Grayson Wheatley, Jack Lochhead, and others).

(3) Knowing that those you work with have no ready-made answer increases everyone's courage to try and find one.

(4) If one of the group finds an answer, this more often than not generates motivation to try a new problem.

(5) To have an inconsistency or "error" explained by a peer is far less painful than have the teacher tell you that you are wrong. Etc., etc.

(W6) Please give examples how social interaction would promote understanding.

Once again my examples will have to be simplistic. The 1st kind of example would be the failure to get what one asks for or what one is trying to get—or to get the wrong thing. I'm talking about very young children and their acquisition of linguistic knowledge. Anyone who has attentively observed a child's language acquisition knows the situation where the child uses a word because it wants something, but the word is inappropriate and therefore does not do what the child expects. The adult misunderstands, gives the wrong thing, and the child gets very irritated. Such moments of failure and perturbation may lead to a change. The child may try another word or the parent may suggest one. Then their child may try the new word the next time—and if it works, the child will have learned. It's a very simple inductive procedure. You hang on to the schemes, the gambits, and the methods that have worked in the past. We all do this, not only in the area of language but in all areas of learning. And this principle has an important corollary that I have often mentioned: We have no reason whatsoever to change what we are doing as long as it produces the desired result.

Which links with the notice of misconceptions in physics or in other teachings. If those conceptions have satisfied what the students demanded of them up to now, the students have no earthly reason to change it. The love of truth will not make them

change it. You have to show them that their conception has limitations and that there are situations where that conception doesn't work. That is one way of getting them interested in learning a new conception, because they all want to widen the range of application of whatever schemes or ideas they have.

(A3) How do we reach shared meanings?

The expression "shared meaning" is misleading. Your meaning and another's are at best compatible. Which is to say, in a given situation, neither reacts in a way that the other could not expect. One only has to get into a discussion of philosophy to realize just how tenuous this compatibility is on the level of abstract concepts. It usually takes a long evening and a good deal of patience before one gets even a dim idea of what the other is trying to say. In a research team, for example, it can take well over a year to establish a workable compatibility with regard to the main terms that are being used. This is what we have called the generation of a consensual domain.

(A33) How can we teach the tentativeness and personal nature of knowledge, yet not undermine the cultural, social reality we have arrived at?

We can not. But, as a constructivist, I feel it is one's duty to proclaim the "tentativeness" of everything one teaches and to warn the students that most, if not all, the "facts" one presents will be seen in a different light two or three decades later. What matters is the process of construction and the fact that this process yields results which seem to be viable at the moment. The cultural and social reality would be a far more liveable and fruitful one if we could do away with the notion that we have the *Truth* and others had better believe it.

(W7) What is the point of talking or lecturing?

Well, in a way, I think, I have answered this. The point is to foster new combinations of concepts. By talking to an audience, I cannot *give* people any new concepts, but I can prod them to combine in different ways the concepts that they have associated with the words I am using. I can *propose* combinations they may not have thought of before or had no occasion to use before. And I can perhaps generate some perturbation about conceptual structures that have been used unthinkingly merely because they felt familiar. If I am not causing *some* conceptual change, my talking—or writing—is useless. But in saying this, I am already in the topic of teaching.

Instruction

(A23,30,32) Implications of C. for a theory of instruction?

There are many. Here I can mention only a few that can be stated briefly.

(1) If we assume that students have to build up their own knowledge, we have to consider that they are not "blank slates." Even 1st-graders have lived for a few years and found many viable ways of dealing with their experiential environment. The knowledge they have, is the only basis on which they can build more. Hence it is crucial for the teacher to get some idea of where they are (what concepts they seem to have and how they relate them).

(2) Whatever a student says in answer to a question (or "problem") is what makes sense to the student at that moment. It has to be taken seriously as such, regardless of how odd or "wrong" it might seem to the teacher. For the student, to be told that it is wrong, is most discouraging and inhibiting. Besides, given the way the student interpreted the question, the answer may actually be a good one.

(3) If teachers want to modify a student's concepts and conceptual structures, they have to try and build up a model of the particular student's own thinking. Models of students' thinking can of course be generalized, but before assuming that a student fits the general pattern one should have some solid evidence that this is a viable assumption in the particular case. It should never be assumed that students' ways of thinking are simple or transparent.

(4) Asking students *how* they got to the answer they gave, is a good way of discovering something about their thinking and opens the way to explaining why a particular answer may not be useful under different circumstances.

(5) If you want to foster students' motivation to delve further into questions which, at first are of no particular interest from the students' point of view, you will have to create situations where the students have an opportunity to experience the pleasure inherent in solving a problem. Simply being told that an answer is "correct" does not do anything for the student's conceptual development if he or she was not interested in the question.

(6) Successful thinking is far more important than "correct" answers. Successful thinking should be rewarded even if it was based on unacceptable premises.

(7) To understand and appreciate students' thinking, the teacher must have an almost infinitely flexible mind (because students sometimes start from premises that seem inconceivable to teachers).

(8) The constructivist teachers can never justify what they teach by claiming that is "true." In mathematics they can show that it derives from certain conventional operations; in science, they can not say more than that it is the best way of conceiving the situation because, at the moment, it's the most effective way of dealing with it.

(A36) How do you activate the mind to construct knowledge?

By letting students struggle with problems of their own choice, helping them (as Maria Montessori said a long time ago) only when they ask for help. At best, the teacher can orient the students' constructing in a fruitful direction, he can never force it. This is, of course, time-consuming; but after they have experienced once or twice the pleasure of finding a solution by their own thinking, they will be quite ready to work on problems suggested by the teacher.

(W2) What is the role of training interactions? Can episodes of training be used to solicitate episodes of teaching?

My presentation was very condensed, and there are many things I had no time to say. Making the distinction between training and teaching does not mean that there is no place for training. I am convinced that some training is very useful, but in itself it is not conducive to understanding. However, there are many experiences for which one needs to be proficient in certain routines. Routines are necessary. You are not going to be a mathematician unless you have automated some of the elementary operations;

but if you have automated them without having grasped their conceptual underpinnings, you are not going to be a mathematician either. Training and teaching have to go hand in hand. If I mostly emphasize teaching, it is because training is common practice in schools anyway.

(A1) How does C. influence problem solving?

By letting the students discover that it can be fun to solve problems. It will not be fun, if the teacher constantly watches that they take the "right" path to the "right" solution. Students often take wholly unexpected, unconventional paths to a solution that is quite viable but perhaps limited in its applicability. If the teachers don't respect this, they merely demonstrate that they are unaware of the history that has led to the present state of the art. That is why, especially in science, I consider it indispensable that students be given a feeling for the long history of magnificent failures.

(W9) Is knowledge really only built from existing pieces? And does meaning only come from prior knowledge?

I think I have already answered this—at least in my way. Knowledge is often built up by combining and recombining available concepts or by trying out new conceptual relations. After the child has acquired a certain level of language, language can be used to suggest and to stimulate new combinations, and so on. And a similar succession of levels can be seen in reflection and abstraction, the processes that generate mathematics and other abstract realms.

(A5) Are the implications of C. the same for mathematics and science education?

Most are, but some are not (see point 8 in the first answer under "Instruction"). In mathematics, for instance, the teacher should explain that the step in calculus that leads from infinitesimal bits to continuity is a conceptual decision, not a logical consequence; just as the decimal system with all its consequences and implications is a conceptual system, not a God-given characteristic of an external "reality." In science, on the other hand, the first thing to make clear is that scientists do not "unveil" the objective order of a pre-existing universe, but invent viable ways of co-ordinating and managing experiences—where the range of experiences is always limited by the particular interests of the given period. The history of science is full of examples that show how theories are superseded when new experiences enter the field of exploration. Old theories, as a rule, are not proven to be "wrong"; they merely turn out to be inadequate in an expanded domain of experience or in the pursuit of new goals. Above all, the constructivist teacher should never present a solution as the only one.

(A7) How can we structure a teacher education program that allows students to construct an understanding of science, teaching, and learners that is consistent with C.?

By making clear that education pursues two goals. First, to foster thinking that does not involve conceptual contradictions and leads to internally consistent results. Second, to introduce students to the consensual domain that governs the discipline at the moment. The "science" of today is, after all, what the scientists of today believe they agree on. But to a constructivist, "agreement" does not entail that the concepts

and conceptual relations used by the people who "agree" are identical; it merely means that, under the given circumstances, they seem compatible (which, to repeat myself, indicates no more than that one is unable to discover discrepancies in one's own and the other's way of speaking and acting).

(A27) If we adopt the radical C. view of knowledge, what changes in the way science teachers talk about the world will be required (i.e., language, terminology)?

Little beyond the fact that what is being talked about is *a particular view of the world*, not the world as such. It is a way of ordering and co-ordinating experience that seems useful and consistent at the moment.

(W2) Technical terms are intensively employed in the teaching and learning of science; what is the status of technical terms (which are rigidly defined) in scientific understanding? Technical terms are memorized*, right?*

That is very good question. Technical terms are somewhat different from the ordinary words that children learn in the first three or four years of their lives. The reason why they are different is that there usually is a good operational definition for technical terms, and the student can be shown or guided to do what is necessary to construct the referent. The operations to produce a viable referent may be physical or they may be conceptual—and in the second case, teaching the term will be more difficult. The physicists' notion of 'energy' is a good example. For the last two years I have been involved with people who do research on physics teaching. As a non-physicist I was at first astonished to see that physics teachers and physicists quite often begin to argue about what energy *actually* is and that there does not seem to be a definition that satisfies everyone. Of course there are definitions in the textbooks, but the physicists tend to say that these definitions reflect a very naive way of thinking about energy. So there are, indeed, difficulties and a non-physicist is not in a position to solve them. All I would say is this: It is no use presenting students with a verbal definition unless they have an opportunity to have some kind of relevant experience. In a laboratory one can show all sorts of simple experiments in which a construct such as energy becomes, if not obvious, at least quite plausible. So much for technical terms.

(A24) Does C. favour divergent instructional strategies? Or is it consistent with a teacher having an agenda?

The "agenda," I would say, is the attainment of the two-fold goal (see Q7 above); instructional strategies may be suggested but not prescribed. Every inspired teacher will develop his or her own. Teaching, after all, is something of an art. It requires not only acquaintance with techniques but also intuition.

(W1) If understanding is in the individual, does the teacher then abdicate any evaluative function?

My answer is no. In fact, the teacher cannot help evaluating what students do and say. Teachers must show the student what they consider inadequate, and they must show *why* it does not work. The constructivist teacher is not concerned with "truth" but with successful operating. It is no use simply telling students that they are wrong. This only decimates such motivation as they may have. To change their way of acting or

thinking, they have to see in their own experience that what they did was not the most successful way of operating.

(A35) Whose construction is to be accepted in a school setting?

The first criterion to decide the acceptability of a "construction" is its viability, that is to say, whether it does or does not what it is supposed to do. If it is viable, one can introduce other criteria, such as simplicity, economy, elegance, convention, etc.

(A18, 37) What are the implications of C. for how we assess student learning?

This is the most difficult question. Before it could be answered satisfactorily, one would have to decide what one wants to teach. As long as evaluation is based on "performance," where performance means the ability to reproduce answers that were part of the instructional process, we are *not* assessing what would be the important "learning" from a constructivist point of view, i.e., the ability to solve new problems. We have to decide whether we want students to develop their ability to think or simply to handle standard procedures and to give standard answers in a limited set of situations. Given sufficient authority, the second can be achieved by rote learning and does not involve the students' conceptual ability. If they pass this kind of test, they may find the satisfaction of holding a job and they will have to discover *other* ways of attaining intellectual satisfaction. Much research is going on in the area of "assessment of cognitive skills" and some new methods may be found. At the moment, all I can think of is this: present the students with a problem they have not encountered before (in the sense that it is conceptually different); observe (infer) how they conceptualize it, and judge what they do to solve it. It is the student's approach that is far more important than the particular solution. By observing the conceptual tools the student is using, one can usually get some inkling as to how far he or she is on the way towards a viable conceptual network for the particular area. Best of all, give them a problem to which there is not yet a standard solution. I realize full well that this is not a satisfactory answer. But then, according to the statistics we read these days, the tests used at present are not satisfactory either.

(A31) Would a constructivist approach to science cause more students to be "better" scientists?

To answer this question, we should first have to agree what it means to be a "better" scientist. From my point of view, I would say yes—but to me a scientist is better if he never forgets that science cannot reveal "objective truth," is forever fallible, and is not the most important thing in the field of human experience. A constructivist attitude is, I believe, a safeguard against the pseudo-religious faith that the search for "truth" justifies all means and can wash its hands of the possible consequences. Constructivists cannot but remain aware of the fact that they themselves are responsible for the way in which they see the world and thus for everything that may follow from their particular way of seeing. Their way of seeing is, in the last analysis, never more than *one* viable way of seeing.

(W10) In a largely positivist world, how do you suggest that constructivism can make a Bridgehead in teacher education?

By having actual and prospective teachers experience that the constructivist approach works. This is not an easy task. But where it has been put into practice (at the University of Georgia, at Purdue University, at Florida State in Tallahassee, and also at my own institute at the University of Massachusetts), our initial fears and doubts have been allayed. At the beginning I was inclined to think that teachers who have taught whatever they teach for 15 or 20 years would be extremely reluctant to change in their approach to teaching. But practice has proved otherwise. If one succeeds in getting teachers to make a serious effort to apply some of the constructivist methodology, even if they don't believe in it, they become enthralled after five or six weeks, not because the results in the children are so wonderful, but because the atmosphere in the classroom has changed. The relation between the children and between the children and the teacher becomes radically different—it turns into a productive relation.

It is an overwhelming experience to come into a classroom of six- or seven-year olds who are all intensely occupied, all doing things that are relevant to what they are supposed to be doing, and it quickly becomes evident that they are enjoying it. Most elementary school teachers find this such a relief that they are very ready to continue.

In other words, it is the success that convinces them. But there are difficulties nevertheless. It takes an enormous amount of stamina to bring about a change of mind in School Boards, in principals, and others in authority. It does not happen in a few weeks. Yet after a year or so, the radical change in the attitude of the children and therefore in the mood of the schoolroom has its effect. If then it can be shown, as is the case now, that after two years the understanding generated in the constructivist classrooms is significantly greater than in traditional schools, more than half the battle has been won.

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