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Needed: A Theory of Instruction

OVER the past several years it has become increasingly clear to me, as to any thinking person today, that both psychology and the field of curriculum design itself suffer jointly from the lack of a theory of instruction. Such a theory of instruction would indeed be interesting just for its own sake, for purely theoretical reasons. There cannot be, for example, a theory of development which leaves somehow to chance the question of the way in which societies pace and structure the experiences with which children come in contact; and to talk about the nature of development without talking about the way in which society does and can structure the sequence, is to be as intellectually foolish as it is to be morally irresponsible. So even if one were seeking only a better theory about the nature of man, one would indeed want a theory of instruction as one of the instruments by which one understood man and how he was shaped by his fellow man.

Yet we also realize that a theory of instruction is about as practical a thing as one could possibly have to guide one in the process of passing on the knowledge, the skills, the point of view and the heart of a culture. Let us, then, see whether we can set forth some possible theorems that might go into a theory of instruction.

Elements of a Theory

What do we mean by a theory of instruction? I found myself beginning this exercise by putting down theorems that tried to separate what we might mean by a theory of instruction from other kinds of theories that have been current. The first thought that occurred to me is that in its very nature a theory of instruction is *prescriptive* and not *descriptive*. Such a theory has the aim of producing particular ends and producing them in ways that we speak of as optimal. It is not a description of what has happened when learning has taken place—it is something which is normative, which gives you something to shoot at and which, in the end, must state something about what

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you do when you put instruction together in the form of courses. Now, this is not a very surprising thing, yet I am struck by the fact that many persons in the field of education have assumed that we could depend on other kinds of theories than the theory of instruction to guide us in this kind of enterprise. For example, I find that the dependence upon learning theory among educators is as touching as it is shocking. The fact of the matter is that the learning theory is not a theory of instruction; it is a theory that describes what takes place while learning is going on and after learning has taken place.

There is no clear-cut way in which one can derive wisdom, ~~or at least~~ implication, from learning theory that will guide him in the constructing of a curriculum. When I say a theory of instruction is prescriptive, I mean it is *before the fact*. It is before learning has taken place and not while and after learning has taken place. Let me give you an example of the kind of difficulty you get into when you assume that you can use the slender reed of learning theory to lean on. Take, for example, the case of programed instruction.

There is in the current doctrine (I will call it) of programed instruction the idea that somehow you should take small steps, that each increment should be a small step. Now, this idea is derived willy-nilly from a theory of learning which states that learning is incremental and goes in small steps. Nowhere in the evidence upon which such a theory is based—and it is only partial evidence—nowhere is there anything that says that simply because learning takes place in small steps the *environment* should be arranged in small steps. And so we set up a curriculum that also has small steps. In doing so we fail to take sight of the fact that, indeed, organisms from vertebrate on up through the highest primate, man, operate by taking large packets of information and breaking these down into their own bite size and that unless they have the opportunity to do that, learning may become stereotyped. At least it is a worthy hypothesis about instruction.

A theory of instruction must concern itself with the relationship between how things are presented and how they are learned. Though I myself have worked hard and long in the vineyard of learning theory, I can do no better than to start by warning the reader away from it. Learning theory is not a theory of instruction. It describes what happened. A theory of instruction is a guide to what to do in order to achieve certain objectives. Unfortunately, we shall have to start pretty nearly at the beginning, for there is very little literature to guide us in this subtle enterprise.

What shall a theory of instruction be about? I would propose that there are four aspects of such a theory. First, a theory of instruction should concern itself with the factors that predispose a child to learn effectively; and there are many such factors that predispose. These are factors which, on the whole, precede the child's entry into our scholastic care. These factors relate to his earliest childhood and indeed one might say that we should provide some theorems for a theory of toys, and for a theory of family, and for a theory of stimulation, because the thing that comes to mind here is the question of what kind of stimulation ought a child to have before he is faced with this formidable thing we call a schoolroom and a teacher. What sorts of identification might he best form? How shall we bring his linguistic level up to a point where he is able to handle things symbolically? I shall not treat further

these predispositions because what I want to do after this introduction of the different aspects of the theory is to go back and have a look at each one of these in detail, so let me pass on now to a second aspect of a theory of instruction.

It should concern itself with the optimal structuring of knowledge. By this, I mean that for any body of knowledge there is a minimal set of propositions, or statements, or images from which one can best generate the rest of what exists within that field. For example, from the conservation theorems plus a little more, a great deal of physics can be reconstructed. This is the "guts" of physics.

Now, I think when we speak of the optimal structuring of knowledge, we probably have three things in mind about this set of underlying propositions. They should have the power of simplifying the diversity of information within the field, somehow rendering the particular redundant, making it clear that this case is just a sub-case of something else, that one fact is not the same as every other fact. I speak of this power of simplification as the economy of a structure. Secondly, such a structure would enable you to generate new propositions, to go beyond the information given. This I would speak of as the productiveness of a structure. And finally, there is another aspect to the structure of knowledge which has to do with the extent to which it increases the manipulability of knowledge. It is classically the case, for example, that when you put something into words it now becomes possible for you to take that thing which before you only intuited in some rough way and to subject it to the combinings and re-combinings that are made possible by the transformative powers of language. And this I want to speak of as the power of a structure. In thinking of structure, then, we shall want to consider economy, productiveness, and power. All of these things are relative to a learner. It does not do to say simply that because physics has great economy, great productiveness, and great power as practiced by a Feinman or a Purcell, that therefore you have children ape those distinguished scientists. You take the child where you find him and give him the structure that is economical, productive and powerful for him and that allows him to grow.

A third aspect of a theory of instruction deals with the optimal sequence that is required for learning. In what order do we present things? If you are presenting the Napoleonic period, where do you start? If you would give a sense of the sixteenth century, do you begin with the fact that mercantile prices and prosperity were going up at a booming rate, whereas the rents that were got by the landlords were not going up because there were long-term leases? You might. If you want to produce drama, you would. But, we will return to that because there is a question of how to give the learner a place from which to take off, something upon which to build. What order to do it? What exercises do you give him to strengthen the sinews of his own thinking? What type of representation do you use? How much particular? How much generality?

Finally, a fourth aspect of a theory of instruction should concern itself with the nature and pacing of rewards and punishments and successes and failures.

To sum up then, a theory of instruction should be constructed around four problems: predispositions, structures, sequences, and consequences.

Predisposition

What can we say about the factors that predispose a student to be a learner? Let us begin with the following simple proposition: that in order to learn or to solve problems, it is necessary that alternatives be explored and that you cannot have effective learning or problem solving without the learner's having the courage and the skill to explore alternative ways of dealing with a problem.

It seems that if you take this as the first proposition concerning predisposition, there are three things that immediately can be said. First, that if this is the case, learning in the presence of a teacher, or a tutor, or an instructor should somehow minimize the risks and the severity of the consequence that follows upon exploration of alternatives. It should be less risky for a child to explore alternatives in the presence of a teacher, than without one present. It is obvious that, at the level of coping with nature in the raw, the child searching for food on his own would stand more risk of eating toadstools and poisoning himself, and thereby bringing exploration to a close.

Yet there are other less obvious things that have to do with the closing down of the exploration of alternatives. A teacher or parent can instill the fear of being a fool. That can surely paralyze the will to explore alternatives, for the moment an unreasonable alternative is made to seem like a foolish one, the inner freedom to explore is limited by the requirements of face saving. The encouragement of exploration of alternatives requires some practical minimization of the severity of consequences following exploration.

It seems to me, further, that one of the ways in which a sense of alternatives to be explored can be opened, is to increase the informativeness of error. To increase the informativeness of error essentially involves making clear to the child what produced a failure. One of the major functions of a teacher is to lead the child to a sense of why he failed. I do not mean why he failed in terms of a characterological analysis; I mean in terms of the nature of what it is that he is doing. If you can somehow make the child aware that his attempted answer is not so much a wrong answer, as an answer to another problem, and then get him back on the track, it becomes possible for the child to reduce the confusion that is produced by picking a wrong alternative. One of the things that, I believe, keeps us from exploring alternatives is precisely the confusion of making the wrong choice.

Still another goad to the exploration of alternatives is through the encouragement of "subversiveness." I mean that you must subvert all of the earlier established constraints against the exploration of alternatives. This kind of subversiveness has to do with a healthy skepticism toward holy cows, prefabricated doctrines, and stuffed shirtliness. Let there be no question or doubt that is "not nice to express." The moment you as teachers lose your role as subversives in this respect, you are doing the child an injustice and yourself an injustice as a teacher. I want to rescue the word "subversion" from the wrong senses to which it has been put in recent years.

When we think about predispositions to learn, we have to bear in mind that the very relationship that we have with our pupils is a privileged relationship involving authority and direction; that is to say, the exchange is uneven. We know; they do not. Since that is the case, it becomes very necessary for us not to

use this implicit authoritative relationship as a means of using our own office as a way of establishing truth and falsity. It is so easy in the mind of the impressionable child to equate truth with Miss Smith!

The nature of learning in a school situation requires at least a dyadic relation; at least two people are involved, and usually many more than two. This obvious point requires that there be some set of minimal social skills that a child brings with him to a learning situation. We do not know much about the nature of these social skills that are required for an exchange of information. The act of exchanging information mutually, or even of accepting information and working on it until you make it your own, is not well understood. In addition to minimum social skills, there are elementary intellectual skills that are necessary for a first encounter with school learning. We "know" this, but we do little either to investigate these elementary skills or to devise ways of strengthening them. I am thinking principally of linguistic skills. Where a child has been socially underprivileged in his early years, it may be necessary for example to look squarely at the situation and say: This child, before he can go on in these subjects, simply needs more linguistic training or all of our words will be just mere wind going by his ears. I do not mean vocabulary, but, rather, the development of the full transformative power of language which our linguists are only now beginning to understand.

It is necessary for the beginning child to have certain kinds of manipulative and almost intuitive geometric skills. We have started studies of children on the borders of the Sahara in the interior of Senegal. We are struck at the difference in the behavior of American children and children in the African bush who do not have toys with mechanical or geometrical constraint to play with. We take it for granted that our children can deal with geometrical forms, put them together and take them apart, yet the fact of the matter is that it should not be taken for granted. The experience of manipulating materials gives our children a stock of images and geometric transformations that permit him to work geometrically and mechanically in a way that our African subjects cannot. These elementary forms of intellectual skills are essential. Is there more that we can do that we are not doing?

My last point before passing on to the topic of structure in learning has to do with attitudes toward the use of mind. These are predisposing factors of an enormously important kind. For example, we know that these vary to some extent, speaking sociologically, by class, by ethnic group, by culture. There is no question, for example, that in terms of social class, very frequently you will find in the lowest social class an attitude toward life that is governed by the concept of luck. This means that there is really nothing you can do by your own efforts, that things happen to a considerable extent by luck. The business of applying the mind, the idea that man has a chance if he will use his mind, is an attitude which is not frequently present and which has to be created. This is an extremely difficult thing to do and I hope no one asks me how do you do it, because I do not know. Yet it is quite clear that we must use the most intelligent opportunism we can muster, to do anything we can to get the idea started that by the use of mind one can increase effectiveness or any other desired state. We also know that different ethnic groups have differ-

ent attitudes toward the use of mind, and again, I do not think we take full advantage of this. The Muslim-African culture, for example, has an attitude toward the use of mind that it should be used principally for grasping the word that has been passed on. This is not the kind of use of mind that makes for what might be called a very active, vigorous mind.

Structure of Knowledge

Now let us turn to the question of the structure of knowledge, its economy, productiveness, and power as related to the capacities of a learner. The first point relates to theorem in the theory of computation proposed by Turing. Turing proposed that any problem that can be solved can be solved by simpler means. That is the theorem. Out of this theorem has come the technology of computing machines. What it says—and it says this only for so-called well-defined problems with unique solutions—is that however complicated the problem, we can break it down into a set of simpler elementary operations and finally end up with operations as simple as: make a mark, move a mark, take the mark out, put the mark back, etc. These elementary operations are then combined into sub-routines that are more complex and then these are combined, etc. The machine succeeds in being practically interesting because it can run off so many of these operations in so short a time. Turing's theorem has a certain relevance to the structure of knowledge; it, in a sense, is another way of stating what by now I am afraid has become an old saw: that any subject can be taught to anybody at any age in some form that is honest. There is always some way in which complicated problems can be reduced to simpler form, simple and step-by-step enough for a child to grasp.

Now, to move ahead one step, I believe it can be said that knowledge about anything can, generally speaking, be represented in three ways, three parallel systems of processing information. One of these is what I call the enactive representation of knowledge. How do you tie a running bowline? You will reply that you can't quite say it or draw it, but that you will show me by tieing one. Try to tell somebody how to ride a bicycle, or ski. It is knowing by doing. It is the way in which the young child on a seesaw "knows" Newton's Law of Moments. He knows that in order to balance two children on the other side he has to get farther out on his side, and this is the Law of Moments, but known enactively. Only with time do children free themselves from this tendency to equate things with the actions directed toward them. We never free ourselves from it completely. Let me, now speak of ikonic representation. If somebody says to me, for example, "What's a square?" I might say, "Well, a square is a set of sets such that the number of elements in each set is equal to the number of sets." This is a good definition of a square, formalistically. Yet the fact of the matter is that there is another way of representing a square, by an image. It isn't a square, it's an image of a square, and it's a useful image —we can start with it. Many of the things we use in representing knowledge have this ikonic property. I use the word "ikonic" because I do not really mean a kind of imitation of nature. Let us not run down the importance of these useful images. They have limits, these representing pictures.

Finally, a third way in which knowledge can get represented is symbolically.

By this I mean in words or in those more powerful versions of words, powerful in one way in any case, mathematical symbols. I think you can turn around the Chinese proverb to the effect that one picture is worth a thousand words. For certain purposes one word is worth a thousand pictures. For example, draw a picture of "implosion"; and yet the idea of implosion as such was one of the basic notions that led to the idea of thermonuclear fusion. Implosion is the concept that results from the application of a contrast transformation on the more familiar concept of explosion. The word was so important that it was classified as top secret during the war. It is this capacity to put things into a symbol system with rules for manipulating, for decomposing and recomposing and transforming and turning symbols on their heads that makes it possible to explore things not present, not picturable, and indeed not in existence.

Now the three modes of representation do not disappear as we grow older; quite to the contrary, they remain with us forever. When we speak of the application of Turing's theorem to the question of structuring of knowledge, it is in reference to the representation forms we have been discussing. Early in life and also early in our mastery of a subject we may have to represent things in terms of what we do with them—in much the same way as a child "knows about" balance beams by knowing what to do on a seesaw. We may then emerge with an image of it, however non-rigorous the image may be. Then and only then can language and symbol systems be applied with some degree of likelihood that their reference will be understood. I do not think I can say anything more important than that. You create a structure, not by starting off with the highest brow symbolic version, but by giving it in the muscles, then in imagery and then giving it in language, with its tools for manipulation. The basic task is to orchestrate the three kinds of representations so that we can lead the child from doing, to imaging what he has done, and finally to symbolization.

Usually in a college catalog when a course is listed it will say something about a "prerequisite." Let me urge that any topic also has internal prerequisites in addition to the things that you are supposed to have mastered beforehand. The internal prerequisites may indeed be just precisely the easier modes of representation that get one to a less rigorous, more imageful or enactive grasp of a subject before it gets converted either into ordinary or mathematical language. The way you get ahead with learning is to translate an idea into those non-rigorous forms that can be understood. Then one can, with their aid, become more precise and powerful. In mathematics such techniques are called "heuristics." Their use often constitutes a prerequisite to grasping a subject in its full depth. This is most of what is meant when we speak of "spiral curriculum."

Optimal Sequence

With respect to the sequence in which material is presented, different sequences are obviously needed to achieve different objectives. The idea of one right sequence is a myth. You have to be quite clear about what kind of learning you are trying to produce before you can specify what is a good sequence for presenting it. There are sequences that can be described for the production of parrots. We use them all the time. But there

is also a sequence that is particularly interesting in that it seems to increase the likelihood that knowledge will be converted into a structure that is economical, productive and powerful—and therefore transferable. It is worth pausing over.

I would like to suggest that if you wanted to do this, the first thing that you might do is to try leading the child to grasp a structure by induction from particular instances. You would give him lots of particular instances and let him recognize their underlying regularity. If you want the child to transfer his learning to new situations you had better give him some practice in transfer while he is learning.

The second thing you might try is the use of contrast in your sequence. The fish will be the last to discover water. Economy of representation often makes it necessary for the child to see the contrasting case. Often concepts are structured in terms of contrast and can only be fully understood in terms of them. To grasp the meaning of commutativity in arithmetic—that $3 \cdot 4 = 4 \cdot 3$—often may require that we recognize the non-commutative case of ordinary language—that for quantifiers, for example, "very much" is not equal to "much very" or as a little girl once put it "black shoe" isn't "shoe black."

Third, if one wants a sequence that is going to produce powerful learning, avoid premature symbolization. Do not give them that word to parrot before they know what it is about either by manipulation or in images. Ask yourselves how much you understand about simultaneous equations.

Fourth, you might try to give the child practice at both leaping and plodding. Let him go by small steps. Then let him take great leaps, huge guesses. Without guessing he is deprived of his rights as a mind. We cannot get all of the evidence. It is often by guessing that we become aware of what we know.

Another question related to sequence has to do with what I would call "revisiting." Rarely is everything learned about anything in one encounter. Yet we seem to be so impelled to cover, to get through the Elizabethan Period, and on through such-and-such period that we forget the obvious point—that the pot is rarely licked clean at one swipe. Perhaps we would do well to take music listening as a model. It is not simply a matter of mastering this subject, or even of converting it into more powerful form. Rather, revisit means an opportunity of connecting what we have learned now with what else we know. Why is such an obvious point so often ignored?

Reward and Punishment

Now the question of pacing reward and punishment for success and failure. First distinguish two states. One is success and failure; the other one is reward and punishment. By success and failure, I mean the end state that is inherent in a task. The problem is solved or not solved or close to solved. By reward and punishment, I mean something quite different. It relates to the consequences that follow upon success and failure—prizes, scoldings, gold stars, etc.

It is often the case that emphasis upon reward and punishment, under the control of an outside agent such as a teacher or parent, diverts attention away from success and failure. In effect, this may take the learning initiative away from the child and give it to the person dispensing the rewards and punishments. This will be the more likely if the learner

is not able to determine the basis of success and failure. One of the great problems in teaching, which usually starts with the teacher being very supportive, is to give the rewarding function back to the learner and the task. Perhaps we can do this by rewarding good errors so that the child becomes aware of the process of problem solving as worthy as well as the fruits of successful outcome. In any case, I wish to mention these matters to suggest that old dogmas about the role of "reinforcement" can be looked at afresh. The independent problem solver is one who rewards and punishes himself by judging the adequacy of his efforts. Equip him with the tools for thinking and let him be his own man.

Some Conclusions

I should warn you, in conclusion, to beware of the likes of us. We do not have a tested theory of instruction to offer you. What is quite plain is that one is needed and I would propose that we work together in its forging.

I warn you for a good reason. Educators are a curiously doctrinal or ideological kind of people. You are given to slogans and fight and bleed in their behalf. You have looked to psychology for help and have often been misled into accepting mere hypotheses as the proven word. It is partly because it is so hard to test the adequacy of ideas in an educational setting.

Now we are living through a great revolution in education. Our survival may depend on its successful outcome —our survival as the human race. I know no group in our society more devoted to the common weal than our educators. In this era of new curricula, new teaching arrangements, new automated devices, your best rudder is a healthy sense of experimentation backed by a skepticism toward educational slogans.

If we are to move toward a serviceable and sturdy theory of instruction—and I think we are—then your greatest contribution will be a willingness to give new ideas a try and full candor in expressing your reactions to how things worked. The prospect is strenuous, but gains to be won are enormous. I wish you well.