In a recent article in this journal, White (1974c) proposed a nine-step process for developing a "validated learning hierarchy" for any given intellectual skill. Implied in this article, but stated more explicitly elsewhere (White, 1974b), is the suggestion that this nine-step process should be used by professional curriculum developers in designing classroom instructional programs. If one were actually to employ White's nine-step process in a real-world instructional situation, however, it would take a considerable number of years, at a conservative estimate, to develop a whole course of instruction or curriculum, given a static and constant knowledge base and no Kuhnian revolutions. One would still have the problem of validating which macroskill needed to be taught before which other macroskill, but this is a problem that the model, as it stands, does not directly address and is somewhat incapable of addressing. Obviously, something is wrong somewhere and what is wrong has to do with more than simply improving the efficiency of the algorithm or shifting to a probabilistic (Cotton et al., 1977) or errors of measurement model (White, 1973).

Although the present writer is of the opinion that the data from "learning hierarchy" experiments can be better and more coherently explained by hierarchical and contextual models of memory, perception, and comprehension than by Gagné's prerequisite learning theory (Gagné, 1968, 1970), or its various restatements (White, 1973, 1974a, 1974b), this opinion does not vitiate the fact that the "learning hierarchy" model is a potentially efficient and easy to apply strategy for developing relatively effective instructional sequences, if it is viewed for what it is, namely, a development strategy or modus operandi of working. Such a view, it should be noted, does not and does not intend to denigrate the Gagné model, or its proponents, nor does the view suggest that the problem is in the algorithm White proposes or the theory underlying it.

Cook (1971), in doing what is now considered to be the classical work on the mathematics of optimal algorithm construction, uncovered what has come to be known as the NP-Complete (Non-Deterministic Polynomial) Problem. An NP-Complete Problem is computationally intractable and thus algorithmically unsolvable. Hundreds of problems are now known in the area of mathematics to be NP-Complete Problems.

Graham (1978), building on Cook's work in studying the combinatorial mathematics of scheduling, empirically found that most sequencing, ordering, or organizational problems of the kind that occur in real-world human activities (e.g., production scheduling and critical path analysis) tended to be NP-Complete Problems. As Graham points out, this discovery completely changed the direction of research on both algorithm construction and scheduling.
as earlier efforts were directed at finding optimal, foolproof, or exact solutions. To quote Graham:

"It might appear that there are natural algorithms, or step-by-step procedures, for constructing highly efficient schedules. That, however, is not the case. Apparently, logical ways of constructing schedules cannot be counted upon to perform equally well in different situations. Some of the commonest and most intuitive scheduling procedures can give rise to unexpected and even seemingly paradoxical results." (p. 124)

Readers familiar with the data and the debate on the issues focused upon in this brief comment should be only too well aware of the paradoxical and even contradictory results that have been reported in numerous studies on a variety of the sequencing and structure models that have been proposed, let alone Gagné’s (e.g., Merrill, 1965; Niedermeyer, Brown, & Sulzen, 1968; Pyatte, 1969; and Partin, 1976). There are, according to Graham (1978), no optimal, exact, or best sequencing algorithms, or even known algorithms in many instances, nor are the prospects for developing such algorithms very promising given Cook’s work on NP-Complete Problems. Emphasis, therefore, has shifted in the areas of mathematics and computer science to the more fruitful direction of determining approximate solutions easily and to finding efficient methods that give close to optimal results. It would seem, quite logically, from the facts that are available that a parallel shift should also be considered in the areas of instructional research and technology.

Realizing that “learning hierarchy,” sequencing, and structuring problems are most probably NP-Complete Problems to some degree in most instances should reduce many of the demands made upon and claims made for the models presently available in the literature. At one level, Cook and Graham’s findings could be construed as supportive of the multistage development model proposed by White or even an explanation of its necessity. Such a construal, however, would in this writer’s opinion be a mistake except for obvious second-thought empirical and nonempirical reflections on first attempt solutions. The thrust of Cook’s and Graham’s findings are that one either modifies one’s theory to achieve tractability or one simply accepts the mathematical and empirical fact that the theory, and its operationalization procedures are only approximations which produce approximate solutions of relative efficiency and practicality. This would indeed seem to be the case with the Gagné model.

The Gagné model is a potentially efficient and easy to apply strategy for developing in many instances relatively effective instructional sequences at the molecular level. It is, moreover, perhaps the only explicitly worked out and well-studied a priori strategy for developing instructional sequences at this level. Why the Gagné model is a potentially efficient and effective strategy is one question, and one can, it should be noted, accept or use the strategy without accepting the theory proposed to explain its effectiveness. However, whether the Gagné model can be employed reliably, approximately, and quickly by a variety of both professional and less professional instructional developers is a much more meaningful instructional technology question and evaluation criterion than the coherence, or full or correct explication of the theory underlying the strategy. This view does not imply that the theoretical questions of importance with respect to this topic be put aside or pursued less vigorously. Rather, the view implies that expecting a sequencing or structuring model to fully deal with at the theoretical level or completely solve what most probably is an NP-Complete (i.e., unsolvable) problem in most instances may be the critical mistake that is presently being made, and a mistake that is relevant to some degree to all of the models that have been proposed or suggested in the area.
COMMENTS AND CRITICISM

References


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AUTHOR'S RESPONSE

Though I might formulate them in a different and perhaps less sophisticated way, I believe I share most of the views Carifio expresses above. But not all of them: as far as the nine-step procedure is concerned, I still think that if one's purpose requires a learning hierarchy that is as exact as possible, which might be the case in many research investigations, then it remains a good procedure to follow. I do agree that it is an impractical procedure for curriculum development, whether carried out by a team or an individual, for a large curriculum or a limited topic. To overcome that impracticality, Gagné and I (White & Gagné, 1978) compared the type of hierarchy that would be obtained by a much simpler, and quite practical, method with that obtained by the full application of the nine steps. We found they were substantially the same. This result should give designers of instruction confidence in using learning hierarchies that have been validated by a less rigorous method than may be necessary for research purposes. If I interpret Carifio's meaning correctly, this action of Gagné's and mine is consistent with the call to modify "one's theory to achieve tractability," which was made above by Carifio.
To an extent, I also agree that "the theory and its operationalization procedures are only approximations which produce approximate solutions of relative efficiency and practicality." I need to explain the partial nature of my agreement.

At what Cariello rather aptly calls the molecular level, it seems to me that the learning hierarchy technique does in fact lead to a set of true and equivalent solutions to the problem of sequencing the intellectual skills that make up the hierarchy. I say a set of equivalent solutions rather than a single one, because with branching hierarchies there can be several sequences which are consistent with the requirement that no skill should be taught before any of its relevant subordinate ones, and these seem to be equally effective (White, 1976). It is useful, however, to distinguish clearly between the sequencing of the skills in a learning hierarchy and another and more important issue of sequencing and structure that concerns the designer of instruction. The hierarchy-based sequence is excellent where the outcome that is intended is the ability to perform a clearly defined intellectual skill. Trembath and White (in press) found that all of a group of students could be taught to perform a very difficult intellectual skill by instruction that followed a sequence consistent with the restriction implied by a learning hierarchy for the skill. However, though the students could perform the skill, we do not know whether they understood it, and instruction generally is concerned with understanding as well as simple achievement. Learning hierarchies have little to say about comprehension, or the sequencing of contextual information which may aid students to comprehend the skeleton of skills of a hierarchy.

Recently, Gagné and I attempted to relate hierarchies to comprehension (Gagné & White, 1978), and currently I am trying to synthesize our ideas with those of Mayer and Greeno (1972), with the intent of producing more complete principles that may be applied quite practically in instruction, and which should help to solve problems of sequencing or structuring courses for comprehension. I agree, though, that in the case of instruction for comprehension the problem probably will lack an exact solution, and that any theory is likely at best to produce only an approximate solution of greater or lesser efficiency depending on how good the theory is, and, as Cariello has done a signal service in reminding us, on how easy it is for a wide range of people to apply it.

Another way of putting this view, which I hope is consistent with that expressed by Cariello, is that it is a mistake to believe that all the decisions that have to be made in instruction can be completely determined by any model of learning or cognition, but such models can be used practically to obtain better solutions to problems of sequence and structure than are likely to be obtained without them.

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