A PLAN FOR THE DEVELOPMENT OF A
CONCEPTUALLY-BASED MATHEMATICS CURRICULUM
FOR DISADVANTAGED CHILDREN
I: THEORETICAL FOUNDATIONS

JOSEPH M. SCANDURA
Mathematics Education Research Group and
University of Pennsylvania, Philadelphia, Pennsylvania

ABSTRACT

The purpose of this two-part article is to point the way towards more sophisticated educational technologies with specific reference to educating the disadvantaged. In Part I, after summarizing some of the current problems in educating the disadvantaged, a new theory of structural learning is proposed and relationships between this theory, educational technology, and curriculum development are made explicit. This conceptual framework then is used as a basis for planning curriculum development in education. Part II shows in more detail how this plan may be applied in the real world with special reference to three specific projects:

(1) An efficient and self-instructional way to diagnose and teach the basic arithmetical skills of addition, subtraction, multiplication, and division.
(2) A systematic way of teaching children how to read critically based on a behavioral analysis of the process in terms of logical reasoning.
(3) A plan for in-service teacher education which deals with mathematical processes (as opposed to content).

1. Introduction

One of the greatest challenges to present day society is that of devising quality educational programs that really work for socially and economically underprivileged children. This need is particularly evident in the three R's. Children who leave school at the minimum age of 16 are frequently functional illiterates. They read haltingly, and with great difficulty; writing is a chore; and even simple arithmetic is a mystery governed by magical rules which they never did fathom.

But, as important as the three R's are, quality education today cannot reasonably be limited to just these basic skills. In order to adequately prepare children for the uncertain needs of tomorrow, we must provide them with fundamental intellectual processes for dealing effectively with the basic problems and decisions they will be confronted with in everyday life.
The "ability to reason logically" is one such process. Research that has been conducted in both this laboratory (Scandura and McGee, 1970) and elsewhere (for example, in Geneva under Piaget) indicates clearly that children, especially disadvantaged children, do not enter school with the ability to reason deductively. The majority of kindergartners we tested were unable to make even the simplest kinds of inferences, made matter-of-factly by normal adults. This suggests that reasoning is a learned skill which may be improved through education. Presumably, the stage is set during earlier years, but surely there is more which can be done beginning at ages 3, 4, and 5, and even 6 or 7.

Although reasoning has long been admired in school, it has almost never been made the object of explicit instruction. This omission may not be so crucial with children who have an opportunity to observe and learn such behavior from others. But how are other children without these opportunities—the underprivileged—to acquire these skills?

Unfortunately, in spite of the great effort and expense which has gone into educational research and development, the problem of educating the underprivileged remains vital and unsolved. There are several reasons for this. First of all, most of the newer programs for the disadvantaged have developed independently of theoretical and empirical considerations; few such programs have been thoroughly evaluated. But more important, there is not universal agreement on the appropriateness of an evaluation method. Rather, the programs frequently have been based on emotion, and later found to be of questionable value. If improvements are noted, it is often impossible to say which aspects of the new curricula are causing the improvement. This being the case, it is impossible to know what to emphasize and what may be safely ignored. Thus, implementing such programs in new settings has been an extremely difficult and frequently impossible task.

If we are to bring about the necessary improvements on a large scale a more systematic approach to the problem will be required. This is particularly crucial in urban education because many of these kinds of problems have never been faced. Consequently, there are relatively few (if any) time-tested ways of dealing with these problems. Without a deeper understanding of the whys and wherefores of education, we can only make blind guesses as to where the solutions lie. Something better is desperately needed.

This fact has been recognized implicitly in a small number of recent development projects. Unlike the majority of projects, these have been based largely on theoretical conceptions of one sort or another. Still, in most cases, the progress to date has been minimal. In other cases, the results are downright disappointing.

There are other reasons why some of the conceptually oriented projects have faltered. First, most of these projects have had inadequate conceptual
bases, or they have not demonstrated the adequacy of these bases. A Computer Assisted Instruction (CAI) project in arithmetic (Suppes, 1967), for example, was based largely on stochastic learning models. While these models have been devised primarily to deal with simple verbal and conceptual learning of the type most typically studied in experimental psychology, the relationships of these concepts with the kinds of learning which take place in schools remain to be established. This group has recently turned some of its attention to automata theory and formal perceptual models as a possible conceptual basis. It is perhaps too early to assess their progress in tying these ideas in with school learning and behavior.

Another conceptually oriented developmental project, Individually Prescribed Instruction (IPI) (Lipson, 1967), emphasized the notion of behavioral objectives. The underlying premise of behavioral objectives is that objectives of the curriculum must be stated in operational terms which lend themselves to testing. Beyond that, there is relatively little, other than task analysis to determine hierarchies of prerequisites (Gagné 1962), although sometimes misapplied ideas adapted from Skinnerian psychology, such as operant conditioning, are used. To be sure, there is some parallel research going on, particularly on criterion-reference testing and on devising more systematic ways of constructing and validating given hierarchies, but the basic ideas have changed little since they were first introduced into education in the early 1960's.

Stating objectives in behavioral terms and ordering tasks according to difficulty appear to be requisite first steps in any attempt to build a conceptually based curriculum. Unfortunately, these steps are not nearly enough. The conceptual framework says little about memory, or motivation, for example. On these topics there are only isolated empirical studies and highly restricted models, neither of which is likely to provide many useful insights into how to go about constructing a curriculum. More adequate conceptualizations will be needed in these areas if we are to provide the best possible kind of education for the underprivileged.

Perhaps even more important, the behavioral objectives framework as it exists deals only with observable behavior, and says nothing about how that behavior is to be generated (Scandura, 1971c). Without such information, explanations and examples frequently have been either inaccurate, vague, or both. This is a particularly important limitation in educating the disadvantaged, because of the difficulties that many of these children have in relating to adults, particularly those adults whose values and expression they do not fully understand.

Another major limitation of the behavioral objectives approach is that it provides no systematic way for providing transfer of learning in a curriculum. Without this capability, the curriculum constructor must
attempt to build all desired features directly into the curriculum. This is nearly an impossible task for all but the most trivial curricula (Scandura, 1971).

A second major reason why conceptually oriented curricula have had limited success is that the relationship between basic research and development or technology has not always been fully understood. Developers have often been indiscriminate in the use made of various conceptualizations. Even worse, in their zeal to make use of research findings, many in the educational establishment have encouraged large-scale developmental efforts on the basis of isolated empirical results.

The more general problem is that not enough attention is given to distinguishing between aspects of a curriculum which are dealt with by a theory or conceptualization, and aspects which are not. Developers are unable to pinpoint which aspects of curricula must be compatible with the theory or conceptualization in question. Correspondingly, it is difficult to distinguish between those aspects of curricula which might lend themselves to systematic treatment, and those which must be dealt with in a more intuitive manner. It is also difficult to coordinate the developmental effort and make clear what the functions are of each person in the development group.

This problem has long been recognized implicitly, but curriculum developers generally have preferred to deal with the problem on a strictly empirical basis. Rather than refine one’s conceptual basis prior to development, revisions are typically made primarily on the basis of post hoc evaluations. My position is that such revision will always be necessary to some extent, but that more attention should be given to the task of keeping this to a minimum.

Third, conceptually based development efforts have run into trouble because there have been few attempts to gear them to present-day educational practice. This is independent of the virtues of these attempts. Implementation of the products which are developed frequently require more abrupt changes in established operating procedures, than many educational systems can take. Many of the conceptually based projects presuppose a particular mode of instruction, which differs in fundamental ways from common practice, that is, from ordinary classroom instruction. In the IPI project, for example, teachers do not teach in the usual sense, but play the role of consultants (to students) and instructional managers. Tutorial CAI projects require even greater changes and expense by virtue of the equipment and physical changes required. At the present time, of course, CAI is still just being explored. Abrupt changes of this sort make it relatively difficult and expensive to implement such programs in many schools. But equally important, attempts at implementation have often met unyielding resistance on the part of teachers and administrators.
2. Purpose

The purpose of this paper is to describe a plan for the development of a conceptually based curriculum in mathematics and allied areas for disadvantaged youth. In order to have a chance for success, the assumption is made that the disadvantaged can learn the three R's, and that they can acquire those fundamental intellectual processes needed in present-day society. The plan described in subsequent sections begins with this assumption and is designed to overcome the three pitfalls mentioned above. Specifically, the plan has the following three characteristics.

(1) It is based on an adequate and integrated conceptual framework which is not only compatible with sound intuition concerning what a good curriculum should be, but makes it possible to go beyond intuition. Since no fully adequate theory exists at present, the framework also is expandable, not only in the sense that it allows for all the major factors involved in the acquisition of complex structured knowledge, but also in the sense that it contains explicit provision for refinements without fundamental revision of the framework itself.

(2) The plan takes into account the relationship between basic science and development; the plan makes explicit provision for both conceptualization and professional know-how and puts each in its proper proportion. In addition, the plan is designed so that additional conceptual information can be fed back into the system as it becomes available, without discarding educational products which already have been developed.

(3) The plan takes immediate needs into account; the products of development can be readily and inexpensively implemented in schools whose student bodies include a high proportion of the disadvantaged. The plan also allows for coordinating development with the most pressing needs of schools.

Although the plan is general, the immediate goal is to show how it might be used to initiate an idealized mathematics curriculum for disadvantaged youth, ages 3 to 12. Ultimately, this curriculum is to be individualized with regard to content, processing skills, such as reasoning, teaching methodology and instructional mode. By instructional mode is meant the nature of the interface between the tutor, teacher, tape recorder, etc., and the students. Although the curriculum will center on mathematics, the emphasis is on fundamentals which are basic to all reasoning, and relationships to other areas. Reading, insofar as this involves extracting simple meanings from the printed and spoken words, writing and specific content in areas other than mathematics are not considered. As with many existing conceptually oriented curricula, the proposed curriculum is framed in operational terms so that it can be evaluated. Unlike the other curricula,
however, the present one lends itself to implementation in stages, without major alteration of the existing school organization at any given stage.

3. Preliminaries

In order to adequately assess the plan itself, it is necessary to understand both the theoretical framework to be used and the specific relationship between research and development proposed here.

3.1. THREE DETERMINISTIC PARTIAL THEORIES OF STRUCTURAL LEARNING

The theoretical framework is described at length in a forthcoming book, *Structural Learning: I The Theory and Empirical Research* (Scandura, forthcoming). A brief description of this theoretical framework is discussed in Scandura (1971a). The overall framework deals explicitly (and in a manner directly relevant to behavior) with epistemological questions, as well as with questions pertaining to human learning and performance. Although the theory deals directly with behavior, it does this in a way which is rather unique among most theories in the behavioristic tradition. Contemporary approaches to theory development in this tradition, as they might apply to structural learning (Suppes, 1967; Scandura, 1967) have been of the following sort:

1. assumptions are made about how individual subjects learn or otherwise perform,
2. predictions are made concerning statistics of the experimental groups involved,
3. the experimental results are used as a basis for either confirmation or disconfirmation of the theory.

While this is what is typically done to test assumptions about how individuals learn, most psychologists recognize that this does not necessarily imply that each individual learns as hypothesized. The intention is simply to determine which assumptions best account for certain group statistics. [Probabilities may also be introduced to enable predictions in situations where all of the necessary information cannot be determined or where it would be unfeasible to do so (Scandura, 1971a)]. Predicting group statistics of course, is a viable goal, and I have nothing against that per se. It would be much better, however, to have a theory which deals directly with the behavior of individual subjects.

This problem has been a central concern of mine for the past several years. It is my contention that any attempt to devise a theory of structural learning which does not deal in a very intimate way with individual predispositions and knowledge will prove fruitless. With naive rodents, and perhaps
with humans, it may be reasonable to think of external stimuli as eliciting responses, when dealing with simple reflex behaviors. In more complex learning situations, this seems unrealistic. What the subject does in any given situation depends critically on what he knows and is trying to do. At best, external stimulation simply provides the occasion for responding.

Although the proposed theory still requires much elaboration and refinement, its basic essentials are reasonably well-established. There are three distinct, complementary and easily identifiable levels of theorizing, each with its own type of empiricism. The first level of theorizing is concerned with knowledge—the problem of how to account for the behaviors of which given subjects are capable. In this partial theory, the rule is taken as the basic unit of analysis. A rule may be said to account for a given class of rule-governed behaviors if, given any stimulus input in the class, the corresponding response may be generated by application of the rule. Hence, the task reduces to the “invention” of a finite set of rules or procedures of one sort or another which provide an adequate account of the behavior in question.

This general idea is not new and has long been an integral part of linguistics. An extension of the idea, involving transformations, was first introduced by Chomsky (1957) building on some earlier insights of Harris. What is new is the idea of allowing rules to operate in higher order fashion, that is, to operate on, and to generate, new lower order classes of rules. This relatively simple conceptual change provides a basis for characterizing quite complex kinds of knowledge. Subjects do not necessarily know or have to be taught explicitly every rule that might be desired. Much of their knowledge is latent in the sense that it can be derived from other information (rules) which is explicitly available.

The second level of theorizing is a generalization of the first partial theory and deals with what I have called “memory-free” theorizing (Scandura, forthcoming). Theorizing at this level is concerned with questions of performance, learning, and motivation in situations where the subject is not hampered by memory or his limited ability to process information. The goal is to introduce psychological mechanisms which explain human learning and performance associated with structured knowledge under these idealized conditions. More particularly, this partial theory deals with the question of how and why available competencies are put to use, and how they are acquired in the first place.

In this theory, all learning is viewed as a problem-solving process. If a subject does not have a rule explicitly available for achieving a given goal, then control is assumed to automatically move to the higher order goal of deriving a rule which will satisfy the original goal. Once such a higher order goal has been satisfied, control is assumed to revert to the original goal so
that the newly derived rule can be applied, and the problem solved. A demonstration of how this simple mechanism may be used to explain behavior in a wide variety of situations is provided in Scandura (forthcoming). Such situations range from how subjects solve (or do not solve) complex problems, to how discoveries are made from instances and how subjects are able to interpret entirely new statements which they have never seen before.

This idealized theory also deals with motivation, although the implications have not yet been drawn out as fully as with learning and performance. Motivation is viewed essentially as a process of goal-selection; it deals with the question of what subjects do in situations where there is a choice of activities, and why they choose the activity they do. It is important to point out, however, that this partial theory deals only with highly structured meaningful materials under idealized conditions, and does not deal with the short-term retention of arbitrary serial lists, for example, which are subject to the effects of the limited processing capacity.

The final level of theorizing also takes into account the limitations imposed on behavior by memory and the limited capacity of human subjects to process information. Some of the preliminary experiments (Scandura, 1971a) conducted to date suggest that although individuals may differ in the amount of information they can process at one time, each individual subject has a fixed finite capacity for processing information. This capacity remains constant over all tasks and presumably for all time. If this is true—and much further evidence is needed before we can confidently say that it is—this could have extremely important implications for the way in which subjects are taught. It would do no good, for example, to teach a child to do mental arithmetic using a procedure which involves an ability to process information which exceeds his capacity. In this case, some alternative would be desired, even if the former procedure happened to be the most effective.

One of the most important implications of the work conducted to date has involved the development of a highly systematic way of determining the memory load characteristics of any given algorithm (rule). This has made it possible to determine, for example, that subtracting numbers by the newer method of borrowing requires a memory load one greater than the memory load required by the older method of equal additions. Thus, the relative efficiency of the two approaches becomes more apparent.

3.2. THE RELATIONSHIP BETWEEN RESEARCH AND DEVELOPMENT IN CURRICULUM DEVELOPMENT

The notion of levels of theory in structural learning is basic to the present view of the relationship between research and development in
curriculum development. Also basic to this view is Simon's (1969) conception of The Sciences of the Artificial. Simon begins his monograph by referring to natural science as knowledge about natural objects and phenomena. Simon's use of the term "artificial science" refers essentially to a science of engineering (designing, composing, synthesizing) products of one sort or another which meet certain requirements. In order to synthesize or engineer something, according to Simon, the scientist must have a purpose or goal, and he must synthesize the elements at his command so as to achieve that goal while taking into account the natural laws governing the operation of these elements and the relationships between them.

As an example of what Simon has in mind, consider the task of constructing a curriculum. In particular, consider the task of identifying the content and basic processes (Scandura, 1971b, Ch. 1) to be included in an idealized pre-elementary and elementary school mathematics curriculum. In this case, the goal is to come up with a curriculum which is optimal in the sense that it provides maximum transfer potential, given the time limitations of a mathematics program for disadvantaged youth, ages 3 to 12. The task of the curriculum engineer is to devise a systematic way of achieving the goal within the constraints imposed by the theory.

An important point, which is only implicit in what Simon says is that it is the goal which determines how much a given theory need be taken into account in the (scientific) engineering of any particular product. This observation provides one reason why the three partial theories proposed above may be useful. They were designed to provide the kind of information needed (or, equivalently, the kind of constraints to be met) in dealing with the various aspects of curriculum construction. For example, in order to identify the content and processes to be included in a curriculum it is sufficient to consider only those conceptualizations (in what Simon calls the "outer environment") which pertain to knowledge. Other conceptual information which may be available, such as information dealing with performance and learning, may be ignored for this purpose. In fact, such information would be entirely irrelevant. On the other hand, if one wanted to deal also with the sequencing of knowledge, the assessment of what a subject knows at any given stage of learning and motivation, then other aspects of the theory would also need to be taken into account. In particular, the engineering would be constrained not only by the theory of knowledge, but by the mechanisms presumed to govern learning, performance, or motivation as the case may be. A curriculum which, in addition, deals explicitly and systematically with memory factors would necessarily have to take the corresponding constraints into account as well.

The notion of partial theories (levels of theorizing) is also helpful in another way. It makes explicit the fact that development can never be
entirely systematic. Although science can encroach on professional art, there will always be some residual. No matter how adequate a conceptualization is available at any given stage in the advance of science, there will always be certain things that need to be dealt with on intuitive grounds.

The approach using partial theories makes it easier to specify which aspects are being dealt with on conceptual grounds. These aspects can be dealt with systematically (that is, engineered). The aspects which must be dealt with on the basis of professional know-how are also identified. Thus, given any conceptualization (for example, a theory of knowledge), the curriculum constructor may systematically engineer certain aspects of the total curriculum design (for example, its content and processes), and then consciously deal with those aspects of the curriculum for which the conceptualization does not provide an adequate basis (for example, sequencing and motivation).

Being explicit about such matters could easily result in more efficient large-scale development efforts. Furthermore, to the extent that the conceptualizations used adequately reflect that aspect of reality to be engineered, the resulting curricula should not only be better, but they should require relatively less revision than would otherwise be necessary. A certain degree of evaluation and revision, of course, will always be necessary. The identification of those aspects of a curriculum project which must be dealt with intuitively also serves to single out critical areas in need of further basic research. Presumably, if improved conceptualizations result from such research, they will provide a basis for engineering subsequent development projects.

4. An Overview of the Plan

Any viable plan for developing a new curriculum for the disadvantaged must strike a balance between immediate needs and long-term goals. In order to satisfy immediate needs, the plan must provide for the early development of curriculum "products" that are useful in schools as they presently exist. At the same time, however, these "products" should be compatible with an idealized overall plan so that work accomplished during earlier stages need not be discarded as further progress is made. This plan should also take into account the current strengths of the total educational system as it impinges on curriculum development, in order to avoid the duplication of activities. For example, large-scale dissemination and promotion might better be accomplished by existing agencies such as private publishing houses and existing government dissemination agencies.

The plan outlined below is designed to satisfy these requirements. This
plan is divided into two distinct but complementary parts. The first deals with engineering an overall idealized curriculum and the second deals with the development of specific curriculum products.

4.1. A PLAN FOR ENGINEERING AN IDEALIZED CURRICULUM—LONG TERM

The first part of the plan involves a systematic attack on the overall problem of devising an idealized and conceptually based curriculum in mathematics, reasoning, and allied subjects for pre-school and elementary school disadvantaged children. Recognizing the enormity of this task, the work to be accomplished under this plan would be primarily of the "engineering" variety. The aim would be to engineer just those aspects of an idealized curriculum which current conceptual knowledge makes possible. That is, where adequate conceptualizations are available, the overall plan is to devise systematic procedures to capitalize on this knowledge and thereby to move in the direction of an idealized conceptually based curriculum.

Of course, even this limited goal will have to be accomplished in stages rather than all at once. The engineering will take time; assuming that adequate resources are available, I would guess that it would take between two and three years to make full engineering use of the conceptualizations already available. It would take longer, of course, for actual development. Furthermore, as additional conceptual knowledge becomes available, it should be possible to elaborate on whatever engineering has already been done, and in this way reduce the amount which must be dealt with intuitively. A point will eventually be reached when further improvement may not be worth the additional effort and expense required. At this point, the job, for all effective purposes, would be finished.

Taking all these things into account, a reasonable first step in the engineering would be to identify the essential content and basic processes of the idealized curriculum. The basic processes would involve detecting regularities, deductive reasoning, memory techniques, etc. This step would not concern itself with how to sequence this knowledge, how to motivate it, and so on. In the present case, the resultant engineering would have the effect of reducing the curriculum to a finite set of rules to be mastered by age 12. It is important to note that this use of the term "curriculum" is more restrictive than that normally implied by educators. In the latter case, "curriculum" typically refers not only to the content to be mastered at the end of some period of time, but also the sequencing of that content, and sometimes the instructional methodology to be used.

This set of rules would constitute what might be called an algorithmic base for the curriculum. That is, all or at least most of the tasks could either be generated by one of the rules directly, or generated by a rule which can
be derived directly or indirectly from them. Identifying such a rule set amounts to building into the curriculum the potential to transfer to the other tasks. An explicit procedure for actually accomplishing this will be described in the next part.

The importance of this step in devising a curriculum for the disadvantaged cannot be overestimated. By forcing those responsible for the construction of curricula to be explicit about what is to be learned, a good part of the guesswork is removed as to what the teacher should emphasize. This is particularly important in working with the disadvantaged. The limited information we have on the subject (Scandura and McGee, 1970) suggests that one of the reasons why the disadvantaged encounter difficulties in school is because they lack many of the needed higher order capabilities—capabilities which other children may learn informally as a result of their enriched environment. The disadvantaged seem able to learn the specifics involved; problems arise in learning how to put these specifics together. If these higher order capabilities are identified and made explicit, there is good reason to believe that these disadvantages in learning may be overcome. Furthermore, if training begins early, it may provide sufficient successful experiences so that children may avoid some of the motivational problems which frequently occur at later stages.

An appropriate next step is to systematically sequence (that is, impose a partial order on) the rules according to their intrinsic difficulty. Task analysis (Gagné, 1962) is one systematic and conceptually based technique available for accomplishing these aims. A variant of this procedure, which applies directly to rules (as opposed to the behaviors rules generate), is presently being used in engineering the arithmetic skills project described in the next section. Although these procedures may provide a good way to begin attacking the problem, detailed prescriptions for dealing with basic processing skills and higher order relationships among different rules are yet to be developed.

After the second stage has been completed, there are any number of directions in which the overall engineering effort might proceed, for example, motivation. By engineering, I am not referring to a finished product or operational method of instruction, but to a systematic plan, say, for motivating one item of knowledge or another. For example, it might be possible to determine how best to go about teaching a child how to organize his world by taking into account the kinds of activities he likes to engage in, such as playing "hopscotch" or playing with toy cars. Information pertaining to memory and information processing impose other kinds of restrictions on the form the curriculum would take in actual practice.

It must be re-emphasized that the goal of this part of the plan is not to actually construct an idealized curriculum. This task would take too long to
accomplish in the way indicated. The actual development must be accomplished in smaller stages which conform to the practical and more immediate needs of the schools. The main purpose of having a comprehensive engineering plan is to provide an engineering bank from which engineered plans and products may be drawn when necessary for specific developmental projects. The availability of such an information bank not only makes the development of specific products more efficient, but it also tends to ensure continuity in the overall development.

4.2. A PLAN FOR DEVELOPING SPECIFIC CURRICULUM PRODUCTS

In addition to engineering an idealized curriculum, the research and development group from the beginning would also engage in the develop-
ment of specific curriculum products. A specific plan for accomplishing this is found in Fig. 1. This plan specifies, in a relatively abstract manner, the sequence of steps required for any development project. (Although it is presented in the form of a flow diagram, the figure is not intended to be viewed as a strictly mechanical procedure.)

According to the plan, the first step is to identify a particular developmental project (a) which is designed to meet a critical need in the kind of school in question, for example, urban schools in poor neighborhoods, and (b) for which there is an adequate conceptual base available. This initial phase of the project would necessarily be the ultimate responsibility of a director (and perhaps an advisory board) of the research and development group. The advice of those in the recipient schools also would be actively sought and given high priority.

The engineering group (step two) is primarily responsible for the following tasks: 1. Refining the technological goal of the project, that is, that aspect of the overall goal which can be dealt with systematically; 2. Devising a strategy for engineering the technological goal, that is, a systematic technique for achieving the goal; 3. Actually performing the necessary engineering and, in conjunction with the developmental group, 4. Identifying those aspects of the project which cannot be successfully engineered. The amount of engineering required for any particular project depends in part on how much long-range engineering had been completed when the project was launched. The engineering for the Phase I projects, for example, would likely have more in the engineering bank to build on.

The membership of the engineering group must be thoroughly familiar and in close contact with the conceptual (basic research) component of the research and development group, in order for this plan to succeed. They must also be highly skilled in the use of whatever techniques are developed, based on these conceptualizations. If they are able to develop new technologies or refine old ones, then so much the better.

The third step is the primary responsibility of the development group. This group is responsible for devising and executing a practical plan for incorporating the engineering into a usable product for the schools. In order to accomplish this, a first step is to identify, with the help of the engineering group, those aspects of the project which must be taken into account in the practical development. Since it is probably unwise to move into large-scale development without first trying out the basic ideas informally in the actual school setting, for example with prototype materials, the development group must also be responsible for evaluation during the formative stages. Only after a prototype works satisfactorily can the development be undertaken on a broader scale. Otherwise, revision of the product, the plan or both are required.
In view of their practical concerns, the development group needs to maintain close contact with the schools. This group would be the main liason between the research and development center itself, and the schools.

While members of the basic research group need as much freedom as possible to pursue their goal of understanding, the general thrust of their research would be directed in two ways. First, the research would focus on the general overall conceptual framework on which the entire project is to be based. Second, the research emphasis, at any particular point in time, is determined dually by the availability of promising leads and the needs of the development group. For example, if a systematic procedure for engineering motivation could be put to good use and a promising conceptual basis for motivation has been partly worked out, then it would be quite appropriate to emphasize motivational research. In order to keep the research group from turning inward, however, the individual members would be encouraged to maintain contact with other professionals in their fields, both throughout the university and elsewhere.

Developing a new product is not an end in itself. In order to put a product to use, it must be integrated into the ongoing curriculum of the school or schools for which it was designed. This requires a special kind of professional, one who is both intimately familiar with the entire project and who is also able to communicate effectively with school personnel. These experts at implementing products are primarily responsible both for devising efficient ways for introducing products into schools and for helping school personnel to implement them. They are also responsible for working with evaluation specialists to ensure that the product in question is properly evaluated.

The main burden of whatever formal evaluation is deemed desirable would be borne by a specialist who is thoroughly familiar with both evaluation techniques and the general aims of the project. Due to the special nature of his role, the specialist would have to work with the school through the implementation group. As a result of the evaluation, both he and the members of the implementation group would, in consultation with members of the development (and possibly the engineering) group, identify inadequacies and make recommendations for further revision. If the product proves successful, it would be turned over to a small dissemination group responsible for insuring that the product gets turned over to appropriate government dissemination agencies or to the private sector. At this point, the project would be finished.

Three things about the plan are particularly worth noting. First, although development followed by formative evaluation frequently results in revision of what has been developed, the proposed plan would tend to minimize the amount of revision required by insuring that at least part of the
product developed is based on systematic conceptually based engineering. Hence, revisions would tend to be of a more superficial nature than they might otherwise be. Second, since the work of certain groups has to be completed before other tasks can begin, it is anticipated that the research and development group as a whole would be engaged in several projects at any one time, once the group has been underway for a while. Third, basic research completed during the life span of the research and development group can be fed back into the system to provide a more adequate or refined conceptual basis for subsequent projects. This added conceptual know-how may be used to initiate entirely new projects, which previously were not feasible, or to further refine a previously developed project which is only minimally effective, yet still is extremely important.

The relationship between basic research and development, of course, is a two-way street. Insights obtained during development concerning problem areas which are not completely understood, such as motivation, may be fed back to the research group for testing, together with possible refinement or extension.

In Part II of this paper, specific projects are described which illustrate practical applications of both long-range and short-range aspects of the plan.

References