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ABSTRACT

This paper presents a general model for conceptualizing and testing the interactions of individual differences and subject-matter characteristics with instructional methods. The model postulates certain ways of classifying the variables of interest in such investigations and of conceptualizing the cause-and-effect relationships among those classes of variables. Implications for both research and theory-construction are discussed, and a resolution of the controversy over the optimal breadth of instructional theories is proposed. The paper also describes research methodology that includes aspects of research design and statistical analysis that facilitate the investigation of those interactions. A variation of analysis of covariance is discussed that allows a continuous variable (the covariate) to be analyzed as a factor, complete with its interactions with all the terms in the basic statistical model. (Author)

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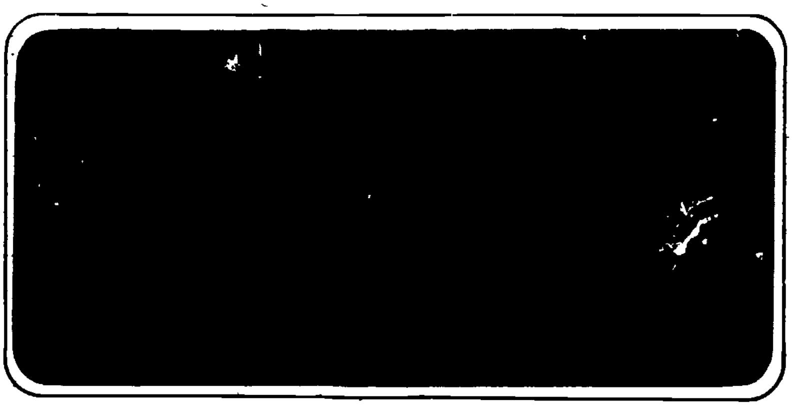

A METHODOLOGY FOR INVESTIGATING THE INTERACTIONS
OF INDIVIDUAL DIFFERENCES AND SUBJECT
MATTER CHARACTERISTICS WITH
INSTRUCTIONAL METHODS

Charles M. Reigeluth

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ABSTRACT

This paper presents a general model for conceptualizing and testing the interactions of individual differences and subject-matter characteristics with instructional methods. The model postulates certain ways of classifying the variables of interest in such investigations and of conceptualizing the cause-and-effect relationships among those classes of variables. Some important implications for both research and theory-construction are discussed, and a resolution of the controversy over the optimal breadth of instructional theories is proposed. Then the paper describes some research methodology which includes aspects of research design and statistical analysis that facilitate the investigation of those interactions. Of particular interest is a variation of analysis of covariance that allows a continuous variable (the covariate) to be analyzed as a factor, complete with its interactions with all the terms in the basic statistical model.

A Methodology For Investigating the Interactions of Individual Differences and Subject Matter Characteristics With Instructional Methods

One of the most important tasks facing educators is the development and use of highly effective, efficient, and appealing methods of instruction. However, this task is complicated by the fact that the effectiveness of many methods varies depending upon such factors as the characteristics of the students or the nature of the subject matter content. Therefore, it is important that researchers and theorists consider the conditions under which different methods should and should not be used. To facilitate the consideration of such contextual conditions, this paper (1) presents a general model as a framework for conceptualizing and testing the interaction effects of student and subject-matter characteristics with instructional methods, and (2) describes a research methodology which includes aspects of research design and statistical analysis that help an investigator to study those interactions.

The purpose of investigating the interactions of individual differences and subject-matter characteristics with instructional methods is to identify the conditions under which different methods of instruction are highly effective. But the way we categorize those conditions and methods can have a large impact on the stability and usefulness of the relationships that are identified between those conditions and methods. Therefore, a matter of great importance is the manner in which we define and classify all the methods and conditions that we wish to investigate; and the ultimate value of any classification scheme that we adopt is determined by the stability and magnitude of the cause-and-effect relationships that are found to exist among those categories.

There are two factors that can influence the value of a classification scheme for instructional conditions and methods: the preciseness of definition of the categories and the nature of the categories. The nature of the categories is determined by the way in which objects, symbols, and events are classified. For instance, trees may be classified according to their age (e.g., seedling, sapling), their kind of leaf (e.g., pine, deciduous), or their genus (e.g., oak, maple). The instructional world can also be "sliced" in different ways. The work of M. David Merrill is based upon the assumption that such categories as physics, English, and algebra are not as useful for predicting the outcomes of instructional methods as are his task/content classification of subject matter (e.g., remember a procedure, use a principle). (See Merrill, Richards, Schmidt & Wood, 1977; Merrill & Wood, 1975.)

With respect to <u>the preciseness of definition</u>, many categories of methods that are frequently used in research and theory construction are not very useful because the stability of their cause-and-effect relationships is jeopardized by their looseness of definition. For instance, "lecture" vs. "discussion group", "inductive" vs. "deductive", and "discovery" vs. "reception" may often vary more within each category than between categories. In such cases, it is necessary to break down these "methods" into their building blocks, and to base one's research and theories on those more clearly-defined <u>strategy components</u>. Such an approach is the major emphasis of M. David Merrill's laboratory at Brigham Young University, and the results of his research have consequently been relatively consistent and "clear"--having fewer interactions and revealing some broad and comprehensive principles of instruction (see Merrill, Richards, Schmidt & Wood, 1977; Merrill & Wood, 1975; Reigeluth & Merrill, Note 1).

A GENERAL MODEL

Reigeluth and Merrill (Note 1) have presented a comprehensive model which classifies instructional variables and indicates ways in which those classes of variables influence each other. First, all variables relating to instruction are categorized as either: methods relating to instruction, outcomes of instruction by which methods can be evaluated, or conditions which influence the outcomes of those methods. Then, within this framework, those categories are further divided as follows (see Figure 1): (1) methods of instruction are divided into strategies for organizing the instruction, strategies for delivering the instruction to the students, and strategies for managing the interaction of the students with the instruction; and (2) conditions influencing the outcomes of instructional methods are classified as to which conditions are likely to have the greatest influence on each class of methods. This does not mean that those classes of conditions are the only conditions which influence each class of methods. The reasons for not including student characteristics in the conditions which interact most strongly with organizational and delivery strategies will be discussed later.

Insert Figure 1 about here

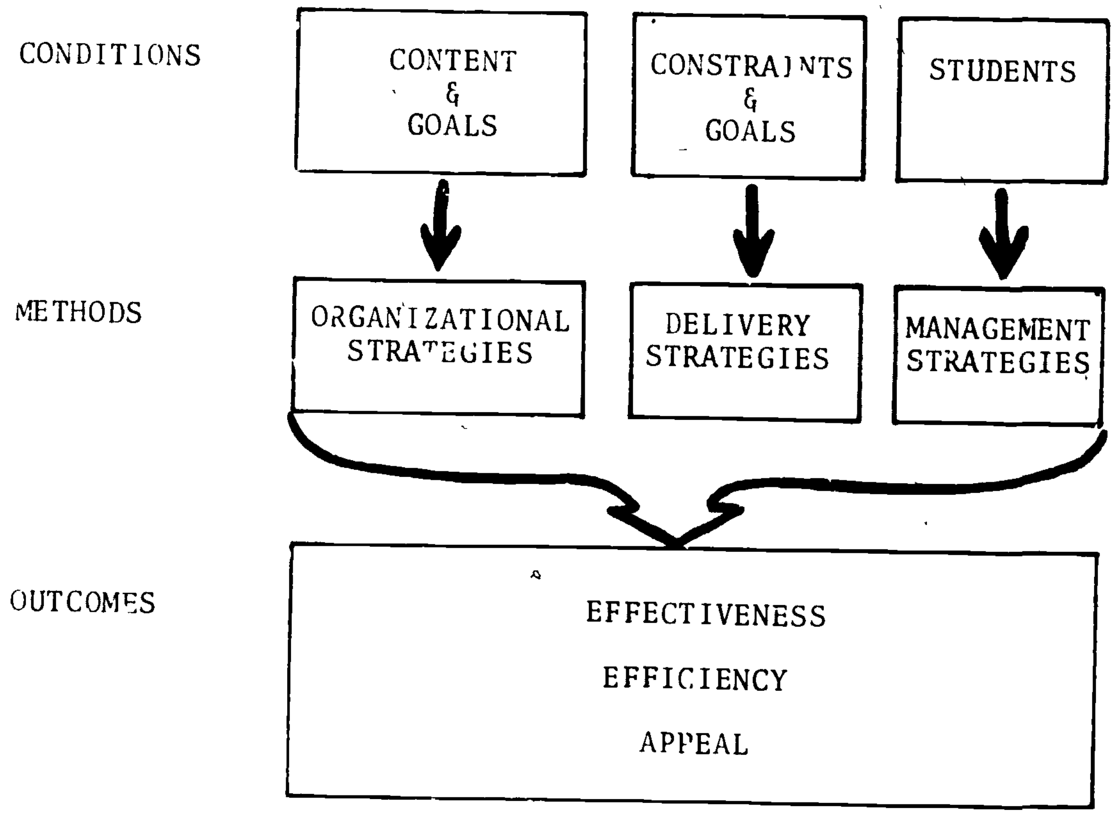


Figure 1. The framework of a comprehensive model showing classes of instructional variables and the major (but by no means only) ways those classes influence each other.

Strategies for organizing the instruction are sometimes referred to as "instructional strategies", and they have been classified as to two types (Reigeluth, Bunderson, & Merrill, in press): (1) presentation strategies, which are methods for organizing the instruction on a single "construct" (concept, principle, etc.), and (2) structural strategies, which are methods for sequencing, synthesizing, and summarizing some related constructs. Much more work has been done on the development of structural strategies, although at least one major effort is currently under way to develop structural strategies (see Reigeluth, Merrill, et. al., Note 2). Presentation strategies include such clearly-defined, elemental methods as: the presentation of a matched nonexample with each example for concept-classification tasks, the presentation of divergent examples for all tasks at the "use" level (e.g., concept-classification, principle-using, procedure-using), and the presentation of mnemonics for all tasks at the "remember" level.

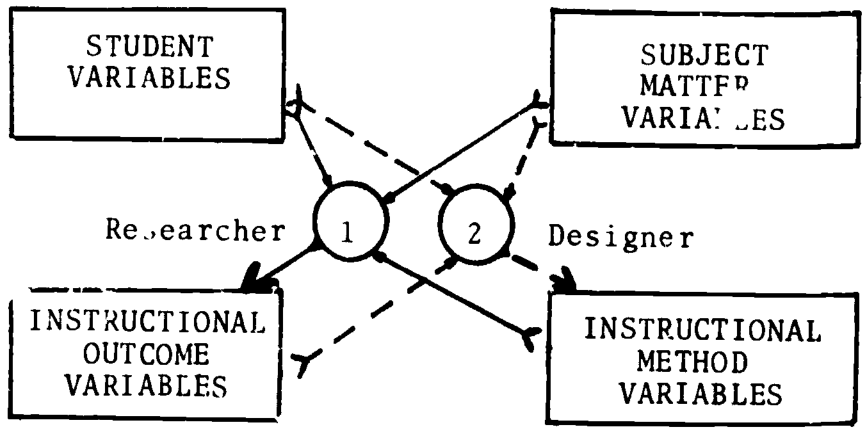
Strategies for delivering the instruction to the students are usually classified as "media", but they of course include such media as teachers, blackboards, workbooks, and textbooks, in addition to such mecnanical media as videotapes, slides, audio tapes, and computers.

Strategies for managing the interaction of the students with the instruction include such things as scheduling the frequency and duration of such interaction, increasing the student's motivation (such as contingency management), maintaining discipline, and even deciding what methods and media a student should have at a given time (see below under The Breadth of Instructional Theories).

For purposes of investigating the interactions of individual differences and subject-matter characteristics with instructional methods, a modification of this comprehensive model (from Reigeluth, Bunderson & Merrill, Note 3), is more useful (see Figure 2). Nevertheless, the distinction among the three kinds of methods is a very valuable one and will play an important part in our later discussion.

Insert Figure 2 about here

The subject-matter characteristics and student characteristics which interest us in this model are only those which interact with instructional methods. For instance, students with higher motivation may be found to score consistently higher on a variety of alternative methods than students of low ability. That main effect is not of interest to us because it has no prescriptive power for improving instruction. On the other hand, if



(1) For an instructional researcher the student variables, the subject matter variables, and the method variables are all independent variables; and their parameters may interact to produce fairly consistent effects on the outcome variables, which are dependent variables.

(2) For an instructional designer the desired outcomes, the student variables, and the subject-matter variables are all independent variables which may also interact; and their parameters are used to prescribe good methods of instruction, which are the dependent variables.

Figure 2. A modification of the comprehensive model, adapted for its particular relevance for investigating the interactions of individual differences and subject-matter characteristics with instructional methods.

high ability students score consistently higher on method A than on method B, while low ability students score consistently higher on method B than on method A, this interaction effect is of great interest because it does have prescriptive power for the use of good methods of instruction. Classifications of subject matter which have similar interaction effects also greatly interest us. Any classification of student characteristics or subject-matter characteristics is valuable to us only to the extent that it is useful for predicting the outcomes of an instructional strategy.

The "outcomes of instruction" which interest us in this model are those which are useful for evaluating the relative merit of each instructional strategy. Such outcomes include the effectiveness of the instruction (e.g., level of conceptual understanding, performance efficiency, transfer, and long-term retention), the efficiency of the instruction (e.g., level of effectiveness in relation to the student time and level of effectiveness in relation to the cost of the instruction), and the appeal of the instruction (how much the student likes it, independently of the content being taught).

From the point of view of the researcher or of the "descriptive theorist", these four classes of instructional variables are related to each other as follows (see

Figure 2). The student variables, the subject matter variables, and the method variables are all independent variables; and their parameters may interact to produce fairly consistent (predictable) effects on the outcome variables, which are dependent variables.

However, from the point of view of the instructional designer or of the "prescriptive theorist", the four classes of variables are related as follows. The desired outcomes, the student variables, and the subject matter variables are all independent variables which also interact; but their parameters are used (thanks to the efforts of researchers and descriptive theorists) to prescribe good methods of instruction, which are the dependent variables.

Implications of the General Model

This general model--for conceptualizing the effects of student and subject-matter characteristics on instructional methods--has important implications for both research and theory construction on individual differences and subject-matter characteristics. First, researchers must be aware of, must control, and must systematically describe the important variables (and their parameters) that were not manipulated in all of the first three classes; and theorists must be careful to specify the parameters of all important variables in the first two classes (student characteristics and subject-matter characteristics) for which their strategies are recommended, or they should specify the likely outcome differences of each strategy for different sets of parameters of those variables. This implication may seem obvious, but unfortunately researchers and theorists alike usually fail to identify such variables as clearly and systematically as they should. This failure greatly impedes the much-needed comprehensive review and comparison of related research--what Glass (1976) referred to as the "meta-analysis" of research.

The Breadth of Instructional Theories

A second implication of this general model is related to the recent controversy over the optimal breadth of instructional theories. Richard Snow, who is well known for his work on individual differences, stated (Snow, 1977) that ATI (aptitude-treatment interaction) "makes general theory impossible"--that instructional theories must be "narrow and local" to be of value. On the other hand, Scandura (1977) stated that instructional theories must be "broad and comprehensive" to be useful. We believe both points of view have merit and can be reconciled with the help of the comprehensive model.

The major source of the difference in opinion over the optimal breadth of instructional theory can be traced to a broader definition by Snow than by Scandura. In reference to our first, comprehensive model (Figure 1), Snow includes all three classes of methods--organizational, delivery, and management--within the scope of instructional theory; whereas I believe Scandura includes only organizational strategies (which are often referred to as instructional strategies--hence their exclusive inclusion in his conception of instructional theory). This difference in the breadth of definition of instructional theory has such a strong impact on beliefs as to the optimal breadth of instructional theory for the following reason: research literature indicates very little ATI with organizational strategies, whereas it indicates very strong ATI with management strategies (hence the configuration of student characteristics in the conditions section of Figure 1).

Our experience and research results indicate that clearly-defined, organizational strategy components, such as those described by Merrill (Merrill, Richards, Schmidt & Wood, 1977; Merrill & Tennyson, 1977; Merrill & Wood, 1975), are usually best for all students or they are best for none.[1] For instance, we believe that all instruction at the "use" level should include the following organizational strategy components; a generality, a large number of examples and practice items, attribute isolation on the examples and on the practice-feedback, a full range of divergence on the examples and practice, generality and instance "helps", and the clear separation and labeling of each of these strategy components. Certainly, as Scandura maintained, "broad and comprehensive" instructional theory can and should be developed--in the area of organizational strategies--and such theories can have high generalizability across schools, as well as across time.

But Snow has an important point with respect to management strategies. If instruction should always contain the same organizational strategy components, the important questions become: when should the student see examples, as opposed to the generality or some practice? how many practice items and examples should a student be given? and when should "helps" or remedial loops be made available? Our experience and research results indicate that the answers to questions like these are extremely sensitive to individual differences, and that they also vary tremendously over time as a student's understanding develops and misconceptions arise and are dispelled. But this problem is not so much one of a difficulty in developing theory (i.e., identifying cause-and-effect relationships) as it is a difficulty in applying that theory. How can Snow or you or I possibly keep track of the momentary and changing "aptitudes" of each and every student and manage to provide just the right kind of instruction (i.e., the right organizational strategy component) for that moment?

The theory is possible and would be generalizable across time and schools: that is, given certain specific combinations of conditions, a particular management strategy would optimize certain outcomes. But that theory could not be applied except perhaps on a sophisticated computer system. And even then, we would have serious doubts about how good that would be for the student. Might it not be better for the student to learn for himself what organizational strategy component s/he needs at any given time? Might it not be bad for the student to be exposed constantly to the "low track" of the curriculum? Maybe a different "track" is what s/he would need to get off the low track.

To us, there is a simple solution to the difficulty of applying knowledge about management strategies and to the questionableness of whether the teacher should apply such knowledge (see Merrill, 1975): <u>learner control</u> over the selection of organizational strategy components. But for such learner control to be effective, the learner must be provided with a certain kind of knowledge and information to enable him/her to make good decisions. Should this kind of learner control prove to be the most effective management strategy with respect to the selection of organizational strategies, instructional theory will be tremendously simplified for this difficult class of instructional methods (i.e., management strategies). And there are strong indications that this is so. The TICCIT (Time-shared Interactive Computer Controlled Instructional Television) system, developed jointly by the Mitre Corporation and Brigham Young University under a grant from the National Science Foundation, has a special "learner control" keyboard, such that with the press of a single button a learner can call up the organizational strategy component that s/he feels s/he would benefit most from at that moment: an easier practice item, the generality, a "help", a hard example, an easy example, etc. And the learner can move on to the next construct (e.g., concept, principle, or procedure) whenever s/he feels ready. There is also an "advisor" to give the learner advice about whether or not s/he understands the construct well enough yet. The National Science Foundation is currently funding a project to investigate the effectiveness, efficiency, and appeal of such learner control, and the results to date are very favorable.

In summary, although it is important that the prescriptions of instructional theories be "narrow and local" (i.e., valid for specific conditions), it is not necessary that the theories themselves be "narrow and local". Organizational theories can be and are broadly generalizable, and management theories can be, too. The major problem is that management theories cannot be applied effectively with respect to the selection of organizational strategies--and they probably even should not be so applied--except by the learner.

We believe that the general model of instructional variables presented above helps provide a sounder basis upon which to conceptualize interaction experiments and to control confounding variables. The remainder of this paper presents several research methodologies that we believe will help to design such experiments and to analyze their data.

SOME RESEARCH METHODOLOGY[2]

We advocate two kinds of research: (1) controlled experiments entailing the manipulation of small numbers of variables in fairly lean instruction, and (2) classroom experiments entailing the testing of whole models of instruction under realistic conditions. Both kinds of research are necessary for the following reasons.

Controlled experiments are conducted under artificial, laboratory-type conditions--conditions that are carefully controlled so as to reduce confounding variables and to isolate pure effects. This kind of research is essential for increasing our understanding of individual strategy variables and how they interact with instructional conditions. However, variables may have significant effects in a certain direction under laboratory conditions, yet their significance may be greatly reduced--and the direction of their effects may even be reversed--under realistic instructional conditions, due to the main and interaction effects of all the other (sometimes unnoticed) variables.

For instance, Reigeluth, Bunderson, and Merrill (in press) hypothesize that an S-shaped curve represents the relationship between the quality of instruction and the effectiveness of that instruction (see Figure 3). Experimenters deliberately design their experimental treatments such that the variable(s) under investigation will increase the quality of the instruction from a-to-b in Figure 3 rather than from c-to-d, so that the contribution of that variable to the effectiveness of instruction will be on the order of magnitude of w-to-x rather than y-to-z. In multiple regression (statistics) an independent variable has a much higher correlation with the dependent variable if it is taken alone than if it is adjusted for all other independent variables. The same is probably true of instructional variables such that the significance of any instructional variable is likely to be of a much lower order of magnitude in real instructional settings than in controlled experiments.

Insert Figure 3 about here

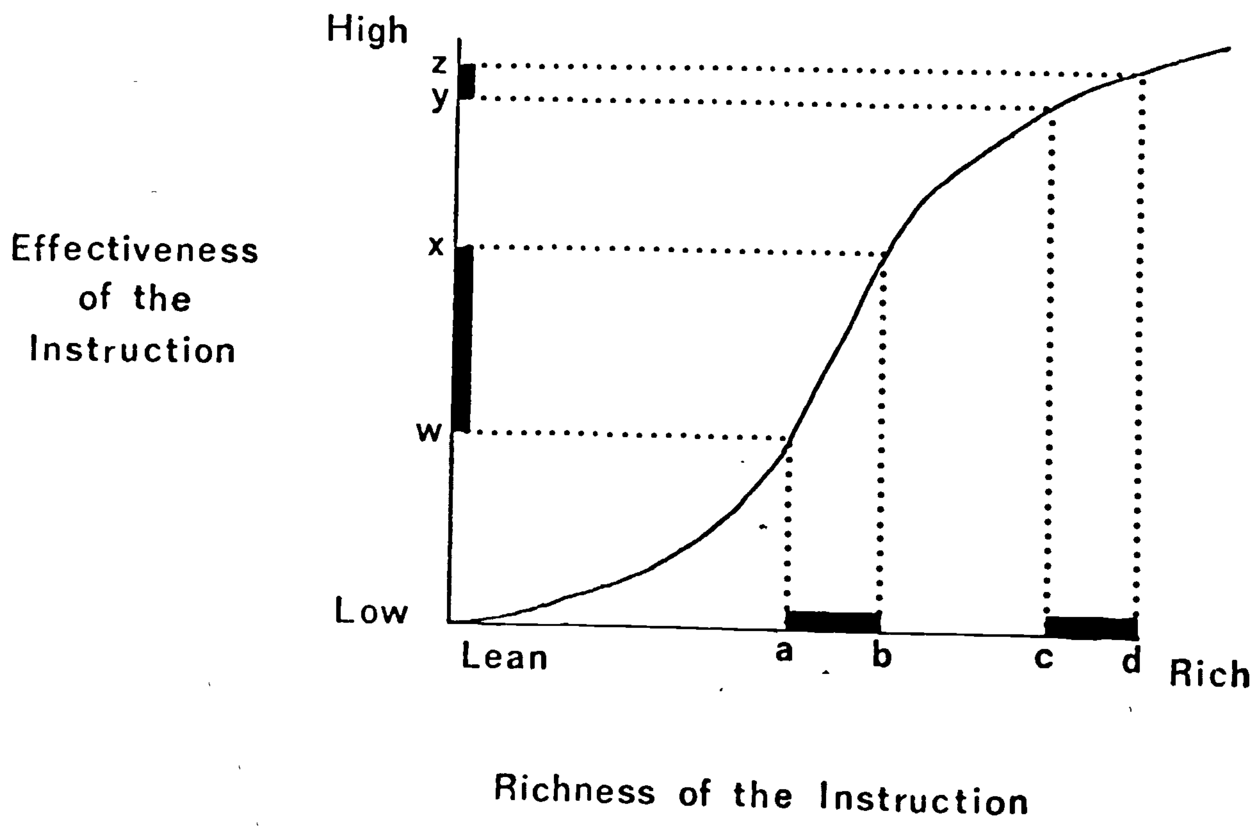


Figure 3. The relationship between the richness of instruction and its effectiveness.

These limitations are serious and require the performance of classroom experiments with realistically rich instructional methods under realistic instructional conditions. Such experiments must test the relative effects of large numbers of instructional strategy components when such components are all present in the instruction, because it is highly likely that many important ones overlap in function and/or interact with each other. It is important not only to determine which strategy components contribute the most to the quality of the instruction, but also to compare their relative contributions with their costs in extra student learning time.

The following should be considered in conducting experiments for both kinds of research. First, all of the variables which might possibly influence instructional outcomes--from Classes 1, 2, and 3 in Figure 2--should be carefully controlled if they are not manipulated. Special care should be taken to avoid confounding among classes of method variables as well as within classes (e.g., to assure that an organizational strategy is not confounded with a management strategy, as well as to assure that two organizational strategies are not confounded). Second, a variety of instructional outcomes should be measured in any experiment. The effectiveness, efficiency, and appeal of the instruction are all important. And it is usually valuable to investigate a variety of important measures of effectiveness--such as conceptual understanding, performance efficiency, transfer, and long-term retention--and of efficiency--such as learning time and the monetary cost of the instruction.

Methodology for Controlled Experiments

For controlled experiments, we have used the following methodology with some success (see Reigeluth, 1977, for an example).

1. Plan the basic experiment. That is, decide which instructional strategy variables you will investigate, and what kind of a "basic" statistical model you will use to analyze the results. (All other strategy variables should be held constant across all treatment groups.)

For example, Reigeluth (1977) investigated the effects of generalities, examples, and practice. The levels were absence and presence of each, giving a 2 x 2 x 2 basic model.

2. Decide which subject-matter characteristics (if any) to manipulate. The different levels of the subject-matter variable can be analyzed as replications of the basic model by having a separate task and a separate set of dependent variables for each level. The students in each treatment group of the basic design receive all replications (tasks) in random order, and all of the

replications must be unrelated tasks. A split-plot statistical design can sometimes be used to make direct comparisons among levels of the subject-matter variable. But often, due to incompatability of such factors as level of chance scores on the posttest, no direct statistical comparison can be made. Nevertheless, an inspection of differences among replications can be very useful.

For example, in the above-mentioned experiment, I used a concept-classification task, a principle-using task, and a procedure-using task as the three replications and found some important differences in the effects of the strategy variables for each type of subject-matter content.

3. Decide which individual differences to investigate. Through stratified random sampling and/or a sufficiently large N, try to assure a representative range of individual differences (within each treatment group) on each student characteristic to be investigated. (Such a balanced representation of student characteristics is really even more important when such characteristics are not investigated, because of probable confounding of results.) Then obtain a valid measure of each student characteristic of interest.

4. Select a method of statistical analysis. We recommend a method of statistical analysis that is easier to use than regression and has several other advantages. It is a variety of ANCOVA (analysis of covariance) in which

you treat the covariate as a factor, complete with its interactions with all the terms in the basic model (usually method variables). First, you should do a separate analysis for each student variable. Enter the variable as a covariate in each replication of the basic model; but also multiply that covariate by each term in the model, and enter the product for each multiplication as an interaction term at the end of the model (just before the error term).

In this manner, an F-test on the covariate (the student characteristic) tells whether that student characteristic has a main effect on each dependent variable (e.g., higher motivation causes higher posttest scores); and an F-test on each interaction tells whether different levels of that student characteristic call for different levels of your strategy variable(s) (e.g., high-motivation students do better on posttest scores when they have control over their learning, whereas low-motivation students do better when there is external control over their learning).

Second, if you suspect that two student characteristics may interact (e.g., high-motivation students may require a different strategy when they have low ability than when they have high ability), both may be entered as covariates in the same model, but you will in effect be doubling the size of the statistical model each time you add a covariate and all its interaction terms.

In relation to ANOVA, this variety of ANCOVA allows you to analyze continuous variables without having to categorize them, which would sacrifice data and power (see Cronbach & Snow, 1977, pp. 60-61). And in relation to regression, this variety of ANCOVA makes it considerably easier to analyze discrete variables (usually the strategy variables) along with the continuous variables (usually the student characteristics) and to analyze the higher-order interactions between the two types of variables.

Methodology for Classroom Experiments

For classroom experiments with realistically rich instructional methods under realistic instructional conditions, we recommend the performance of two types of experiments: (1) a correlational study--to determine the validity and importance (i.e., contribution to student performance) of each of a large number of instructional strategy components (when in combination with all the other components)--and (2) an experimental study--to test the relative effectiveness and the relative cost effectiveness (in terms of student learning time) of the most important strategy components (as identified in the correlational study) in combination with each other, under more carefully controlled conditions. An alternative to performing these two experiments in tandem would be to use a matrix design. This would test individual interactions among methods more effectively; but it would require an experiment of too large a scope and expense to be feasible for many researchers; and the problem of testing interactions can be largely overcome (see below under procedures for the experimental study).

We recommend the following procedure for the correlational study.

1. Plan the basic experiment. Decide which instructional strategy variables you would like to study together. You should select a relatively large number of variables, especially ones that you think are likely to influence each other. In this first experiment no attempt need be made to investigate the interactions of student characteristics (although it could be done by performing a complicated split-plot ANCOVA analysis of individual data within each segment[3] and for each strategy--in such a case, valid measures of student aptitudes at the time of the instruction would have to be available).

2. Select existing instruction. Find some "segments"[3] of classroom instruction that have already been taught and for which test records and the written instructional materials used are still available. Select from those segments on the following criteria: (1) a high burden of the instruction was assumed by a single source of written instruction, (2) there is a high likelihood that all or most of the students had already mastered all of the

learning prerequisites, and (3) there is a low probability of student prefamiliarity with the content of the segment. The segments selected should be as homogeneous as possible on these three criteria, and there should be a fairly large number of segments, since segments are the observational units.

3. Identify performance measures. For each segment identify those test items which measure student performance on that segment. Then calculate the mean score (and, if you wish, the standard deviation) for each segment.

4. Rate each segment. Analyze the written instructional materials that were used for each segment to determine which of the strategy components were used and to what extent each of those components was used. Then rate each segment (on perhaps a five-point scale) as to its level of effectiveness on each strategy component. That level of effectiveness will probably depend upon the "task level" (see Merrill, Richards, Schmidt, & Wood, 1977) of the test items used in #3 above (e.g., remember an instance, use a generality).

5. Perform the correlation. For each strategy component, test the rating on each segment for correlation with the mean test score on the same segment. The resulting correlation coefficient for each strategy component is a

basis (a) for inferring which components significantly raise test scores and (b) for rank-ordering those components on the basis of how much each contributes to student performance, given the simultaneous implementation of all the other strategy components.

If you wish to study the interactions of subject-matter characteristics, you may classify the segments according to type of subject-matter content and do a separate correlation for each group of segments; or to test subject matter main effects and interaction effects, you could use the kind of ANCOVA described above, with type of subject-matter content as a factor and with the segment ratings on each strategy variable as the covariate. A composite rating of all method variables on each segment could also be tested for correlation with mean test scores on each segment to see how much of the total variance is accounted for by the method variables used.

6. Repeat for new methods, if desired. If none of the methods was very highly correlated, you may want to try to identify other strategy components, and repeat the above five steps with the same student performance data but with the new ratings for the new strategy components.

We recommend the following procedure for the experimental study.

1) Select the independent variables. Select the strategy variables that were identified in the correlation study as contributing the most to student performance. There should probably be a maximum of eight or ten different strategy variables. Also select the student and subject-matter variables whose interactions you would like to investigate, and find suitable measures for the student variables.

2) Create the treatments. Select at least one segment of instruction for each level of your subject-matter variable, and if possible select segments that are a part of an on-going course. Having several segments for each level of your subject-matter variable will increase the reliability and external validity of your experiment, especially if they are administered at different schools. The segments you select should have minimal student prefamiliarity and minimal learning prerequisites that cannot be assumed of the students.

Design one treatment by including in the instruction on the segments you selected all the strategy components that you wish to investigate (and any others that you think real-world instruction ought to have). Then create additional treatments by successively deleting one strategy component (that you wish to investigate) at a time, starting with the component that contributed the least to student performance in the correlation study. This will result in the creation of treatments ranging from one that has just one of the strategy components being manipulated (the most important one) to a treatment that has all of the components being manipulated. You should also create a control group which has no instruction.

3) Choose the dependent variables. A variety of dependent variables should be used, so as to measure the effectiveness, efficiency, and appeal of the instruction. Scores on a variety of tests would represent the measures of the change in instructional effectiveness associated with each strategy component and its interactions; and the learning time data would provide a measure of the change in instructional efficiency associated with each strategy component and its interactions (effectiveness divided by learning time). Thus, both student learning time and student posttest scores should be allowed to vary (as they do in most real-world instructional settings), and they should both be used as dependent variables. In consideration of Cronbach and Snow's (1977, pp. 44-45) objection to allowing learning time to vary, we advocate the use of an analysis of covariance to statistically control time to isolate the effects of the independent variables on posttest scores, and vice versa. A multivariate analysis could

also be used to investigate the overall effects of the treatments on both types of dependent variables. Of course, for the efficiency measure (effectiveness divided by learning time), the dependent variables would not be covaried on each her. This choice of dependent variables will allow a rank-ordering of strategy components on the basis of their cost-benefit value for being used in instruction for different kinds of subject matter.

4) Decide on a method of statistical analysis. There is only one factor for instructional methods: each treatment represents a different level of that factor. The significance and magnitude of the differences in the means and standard deviations of successive treatments (for both posttest scores and learning time) are the statistics of major interest, because you want to know which strategy components, when added to and in combination (interaction) with the other important strategy components, significantly increase the effectiveness, efficiency, and/or appeal of the instruction. The least important method variables, as determined by the correlation study, were added last in the formation of the treatments in hopes that the resulting treatment effectiveness means, when plotted against the levels of instructional method, would result in a curve similar to that in Figure 3. This could be tested by

simply plotting the treatment means or by using more sophisticated techniques, such as polynomials or fitting an exponential.

If such a curve is not approximated, then untested interactions could invalidate such a different rank-ordering of the strategy components. Therefore, it would be advisable to redesign the treatments by successively adding the strategy components in their order of importance as indicated by this most recent data; and then rerun the experiment. But if the curve is fairly closely approximated, a simple ANOVA with post-hoc comparisons of adjacent means will provide the necessary statistics for deciding which strategy components, when added to and interacting with the other important strategy components, do and do not significantly increase the effectiveness, efficiency, and appeal of the instruction for each type of subject matter.

Interactions with student characteristics can also be investigated by using the above-mentioned variety of ANCOVA, using the covariate (student variable) as a factor, complete with its interactions with every term in the basic model.

Summary

We propose that the general model of instructional variables presented in the first half of this paper helps provide a sounder basis upon which to conceptualize interaction experiments and to control confounding variables.

We also propose that the research methodologies discussed in the second half of this paper help to provide sound ways for designing such experiments and for analyzing their data.

Reference Notes

1. Reigeluth, C.M., & Merrill M.D. Classes of instructional variables, Instructional Research Report. Provo, Utah; Courseware, Inc., in press.

2. Reigeluth, C.M., & Merrill, M.D., Wilson, B., Norton, R., & Spiller, R. The Structural Strategy Diagnostic Profile Project: a progress report. Instructional Research Report. Provo, Utah; Courseware, Inc., in press.

3. Reigeluth, C.M., Bunderson, C.V., & Merrill, M.D. Is there a design science of instruction? BYU Instructional Science Report, No. 57, 1977.

References

Cronbach, L.J., & Snow, R.E. Aptitudes and instructional methods: A handbook for research on interactions. New York: Irvington, 1977.

Glass, G.V. Primary, secondary, and meta-analysis of research. Educational Researcher, November 1976, pp. 3-8.

Merrill, M.D. Learner control: Beyond aptitude-treatment interactions. A V Communications Review, 1975, 23, 217-226.

Merrill, M.D., Richards, R.A., Schmidt, R.V., & Wood, N.A. The instructional strategy diagnostic profile training manual. San Diego: Courseware, Inc., 1977.

Merrill, M.D., & Tennyson, R.D. Teaching concepts: An instructional design guide. Englewood Cliffs, N.J.: Educational Technology Publications, 1977.

Merrill, M.D., & Wood, N.D. Instructional strategies: A preliminary taxonomy. Columbus, Ohio: Ohio State University, 1974. (ERIC Document Reproduction Service No. SEo18-771.)

Merrill, M.D., & Wood, N.A. Rules for effective instructional strategies. Instructional Design Series: Orem, Utah: Courseware, Inc., 1975.

Reigeluth, C.M. Effects of generalities, examples, and practice: Instructional outcomes for concept-classification, principle-using, and procedure-using tasks. Doctoral dissertation, Brigham Young University, 1977.

Reigeluth, C.M., Bunderson, C.V., & Merrill, M.D. The structure of subject matter content and its instructional design implications. Instructional Science, in press.

Scandura, J.M. Systems/cybernetic/structural approach to instructional theory: A synthesis. In J.M. Scandura, Recent advances in instructional theory I. A symposium presented at the annual convention of the American Educational Research Association, New York, 1977.

Snow, R.E. The place of individual differences in instructional theory. In J.M. Scandura, Recent advances in instructional theory I. A symposium presented at the annual convention of the American Educational Research Association, New York, 1977. Also in Educational Researcher, November 1977, pp. 11-15.

Footnotes

[1]There are some exceptions, such as generalities not being as effective for younger children as for more mature learners; but exceptions appear to be few.

[2]I am deeply indebted to Melvin Carter of the Statistics Department at Brigham Young University for his contributions to the statistical methodologies discussed herein, especially the little-known variety of ANCOVA that uses the covariate as a factor in the analysis.

[3]Segment as used here refers to the instruction on a single concept, principle, etc.

Figure Captions

Figure 1. The framework of a comprehen-ive model showing classes of instructional variables and the major (but by no means only) ways those classes influence each other.

Figure 2. A modification of the comprehensive model, adapted for i[illegible] [illegible]ticular relevance for investigating the interactions of individual differences and subject-matter characteristics with instructional methods.

Figure 3. The relationship between the richness of instruction and its effectiveness.

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No. 66 Isolation of Generality Statements and Instances, Wayne C. Wilcox, Joseph C. McLachlan and M. David Merrill, July 1977.

No. 67 A Methodology for Investigating the Interactions of Individual Differences and Subject Matter Characteristics with Instructional Methods, Charles M. Reigeluth, February 1978.