Science Approach To Instructional Development

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The Benefits of Science

The word "science" is commonly used in today's vocabulary to label that realm of activity which takes the "guess-work" out of some process. Science contributes to this effort in two major ways. The first is through the scientific *process*. Though the scientific process can be inductive, deductive, or some combination of the two, every scientific process contains three elements; observations, hypotheses, and empirical tests. The second contribution of science is its *products*: the knowledge base of theories and principles.. This knowledge base is derived from scientific investigation, which demands that it be tested for reliability and validity. Through the use of the process and products of science, one can increase the level of effectiveness and efficiency in any field. In a field such as Instructional Development, this is crucial.

Approaches to Instructional Development

Traditionally, there have been three approaches to instructional development (Reigeluth, Bunderson, & Merrill, 1978). One is the *artistic* approach, which relies on intuition. Another is the *empirical* approach, which relies on trial-and-revision. The third is the *scientific* approach, which relies on both science as a *product* and science as a *process*. Although it is easy to identify these three approaches in principle, they are seldom found in pure form in practice. What actually (and properly) is found are design processes which incorporate elements of all three: intuition, trial-and-revision, and validated principles and theories. However, there is currently a trend within instructional development for developers to decrease their reliance on intuition and trial-and-revision by increasing their reliance on the growing body of validated products and processes of instructional science. Although we do not anticipate that the scientific approach will ever completely eliminate reliance on either intuition or trial-and-revision, we do see the current trend improving our ability to efficiently produce highly effective instructional resources.

The *artistic approach* is valuable in that it provides the ability to deal with problems for which science has not yet developed solutions. As artistic genius can organize a few thousand tonal intervals into a fugue, it can also organize a few thousand ideas into an effective instructional program. However, what is required is a method which doesn't rely on such a rare commodity as genius. Geniuses, after all are both difficult to find and very expensive to hire. It is doubtful that there are enough good instructional "artists" to go around or that they are affordable for most instructional endeavors.

An alternative to the artistic approach is the *empirical approach*, which uses the information from trial-and-revision, rather than genius, as its principal source of prescriptions. This method provides an increased measure of cost efficiency because it uses skills possessed by a larger number of people (who are therefore less expensive to hire). However, there are problems with this approach. First, it is still not very efficient; and second, it may never result in the accomplishment of the instructional goals. Trial-and-revision is not tied to any extant knowledge base of verified principles, models, or theories of instruction. Hence, each revised prescription is almost as uninformed as the last. As with shots in the dark, you may know that you didn't hit anything, but you don't know where to shoot next. As Tennyson and Boutwell (1974) summarize,

> *. . . the tryout-revise cycle must be repeated many times, thus inflating the cost of instructional development and delaying attainment of optimal performance levels or instructional efficiency* (p. 45.).

Because of the "guess-work" demanded by the artistic and empirical approaches, Instructional Development recognizes the requirement to move towards increased use of the *scientific approach*. And because of the growing body of validated knowledge about instruction, the scientific approach is simultaneously becoming more useful. Earlier we indicated that the process of instructional development could use science in two ways: as the process of observe-hypothesize-test, and as a knowledge base of verified principles and theories. In the following sections, we will discuss the process of instructional development and suggest possible areas within the process where science as process and as product could most benefit.

The scientific approach to Instructional Development relies on three different kinds of professionals (Reigeluth, Bunderson, & Merrill, 1978): instructional scientists, instructional technologists, and instructional developers (although many individuals wear two or even all three of those "hats"). Instructional scientists contribute the basic, scientific, knowledge base of principles, theories, and models of instruction. Instructional technologists contribute efficient procedures for implementing those principles, etc., in the development of instruction. And instructional developers use those procedures to create actual instruction. (In actuality, many instructional developers are also technologists, using validated principles to generate their own procedures, as well as using those procedures to create instruction.) The knowledge afforded by instructional theory is translated to actual instruction through procedures afforded by instructional technology. The developer's view of instructional science is represented in Figure 1.

A scientific approach employs a scientific *process* which utilizes the scientific *knowledge base*. This scientific *process* can be observed in action under the rubrics of "development procedures" or "development models." The various development models (see Andrews & Good-

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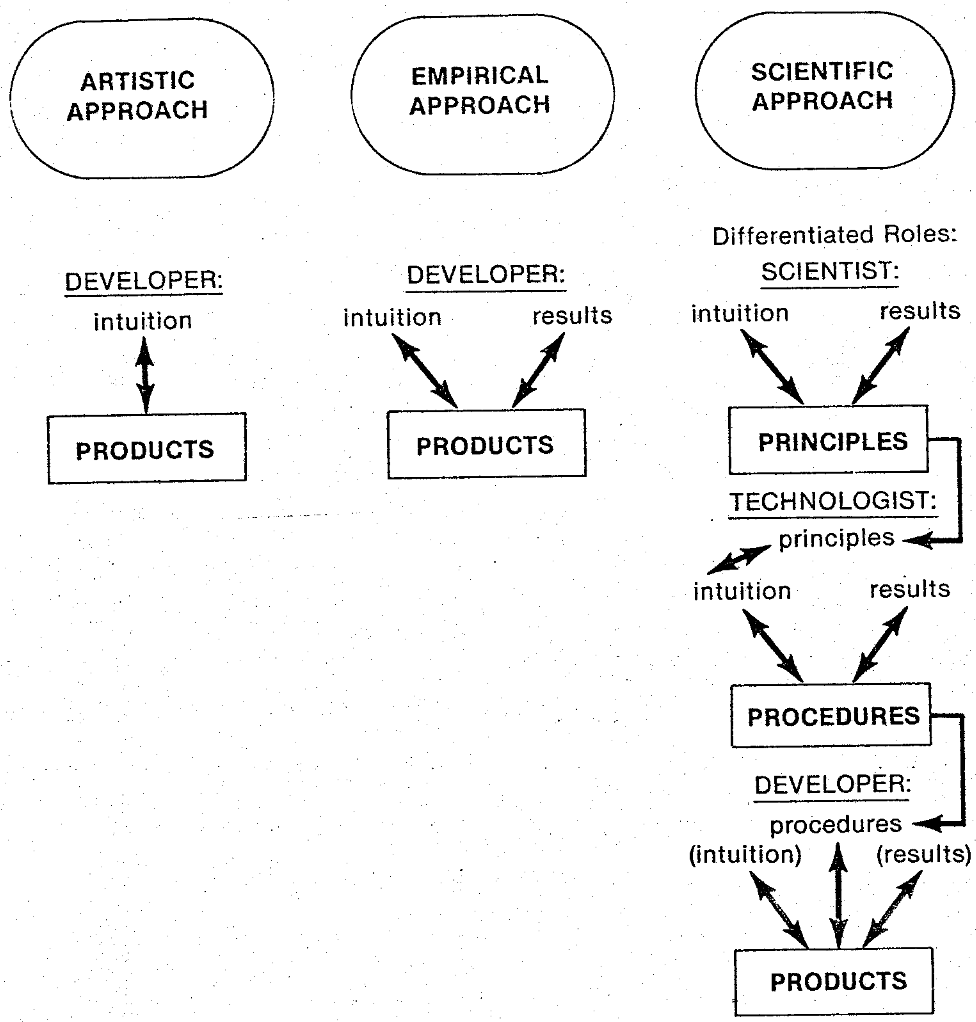

Figure 1. Three approaches to instructional development and the differentiation of roles within the scientific approach.

son, 1980, for a review), though slightly different in practice, are generally similar in intent. They each contain the observe-hypothesize-test components of any scientific process. Instructional developers know these components by the names: (1) front-end analysis, (2) instructional strategy prescription, and (3) formative evaluation.

The synergy of a scientific process and a scientific knowledge base is crucial to the "scientificness" of any ID effort. One could say that even if a scientific process were followed, the absence of a scientific knowledge base as input for the strategy prescription would negate many of the benefits of the process. For example, the trial-and-revision approach to instructional development is commonly used with a scientific ISD process. But the input from front-end analyses is, in this case, used to prescribe the instructional strategy without the additional input of the knowledge base. Without the information contributed by the instructional science knowledge base, the analyses and hypotheses are undirected; they are shots in the dark. The next section of this paper discusses the scientific knowledge base, and the last section discusses the scientific process for ID.

Scientific Knowledge Base for ID

What is the scientific knowledge base for instruction like? One component of it is *prescriptive principles* of instruction. The following are some examples:

1. To facilitate acquisition of an idea at the application level of cognitive processing, provide examples and practice in addition to a statement of the idea (see e.g., Merrill, Reigeluth, & Faust, 1979).
2. To facilitate acquisition of any knowledge at the remember level of performance, provide a mnemonic (see e.g., Lindsay & Norman 1977, pp. 359-364).
3. To facilitate long-term retention, use a general-to-detailed sequence (so that an idea or fact is not presented until after its "ideational scaffolding" has been learned—see e.g., Ausubel, 1968).
4. To increase low motivation, include an incongruity that is related to an idea or set of ideas before presenting those ideas (see e.g., Keller, 1979).

Of course, such prescriptive principles have been derived from *descriptive principles*, such as: including an incongruity that is related to an idea or set of ideas before presenting those ideas causes increases in learner motivation if that motivation was low-to-moderate to begin with. (For more about the relationships between descriptive and prescriptive principles of instruction, see Landa, in press.) A prescriptive principle should state: (1) a desired *outcome* or outcomes, (2) a *method* variable, or "instructional action," which is fairly precise and specific, and (3) *conditions*, if any, under which the method should be used to influence the outcome (such as kind of content, kind of student, kind of setting). See Fleming and Levie (1978) for a fairly extensive listing of principles of instruction.

Although helpful, such piecemeal prescriptions are, from the point of view of instructional developers, inadequate. What is necessary is the combination of such prescriptions into "optimal" *models* of instruction. An optimal model is an integrated set of prescriptions that are believed to be superior to any other known combination of prescriptions. Naturally, its "optimality" will hold only for a limited domain of conditions, such as for a certain kind of educational goal or objective, a certain kind of content, a certain kind of student, or a certain kind of instructional setting. Hence, there must be a basis for prescribing the use of each model of instruction. A set of models plus the bases for prescribing them are collectively called a *prescriptive theory* of instruction. The following is a very brief example of a theory and a model of instruction.

Merrill's Component Display Theory

Merrill's is a prescriptive theory that is comprised of (1) *six basic models* of instruction, each of which can be used in varying degrees of richness, and (2) a unique *system for prescribing those models* on the basis of the desired level of performance as indicated by the objective. The degree of richness of the model is then prescribed on the basis of the difficulty of the objective in relation to the ability level of the students. Also, additions (in the form of more precise prescriptions) are made to each basic model on the basis of the type of content in the objective.

Each of the six basic models of instruction integrates knowledge about how to optimize instruction for one of six levels of performance for any given idea; and each level of performance corresponds to a different level of cognitive processing for any given idea. The most fundamental difference occurs between objectives requiring *recall*, those requiring *application*, and those requiring *discovery*. (The other differences will not be discussed here.)

For the most common level of performance—application—this theory calls for presenting three major strategy components: (1) a *generality*, such as the statement of a principle or the definition of a concept, (2) *instances* showing the application of that generality, such as demonstrations of the principle or examples of the concept, and (3) *practice* in applying that generality to new instances, such as solving a new problem or classifying a new example of the concept. The practice should always be followed by *feedback* as to whether the student's answer was right or wrong and why. The instances and practice items should be *different* from each other in as many ways as the student is likely to encounter in the real world; and they should be arranged in a *progression of difficulty* from easy to difficult (which may include variation in response mode as well as manipulation of variable attributes). Moreover, in order to facilitate *learner control*, the generality, instances, practice, and feedback should all be clearly *separated and labeled* rather than run together in a continuous prose passage.

In order to increase the *richness* of this model, the number of instances and practice items could gradually be increased. In addition, each of the three major strategy components (generality, instances, and practice) could be enriched with such secondary strategy components as (1) an *alternative representation* (e.g., a diagram, picture, or flow chart), and (2) an *attention-focusing device* (e.g., underlining, exploded diagrams, or common errors). The richest version of this model would include a large number of instances and practice items as well as both of the secondary strategy components described above (plus some that have not been mentioned here). For an idea or objective that is easy in relation to student ability, however, the generality alone might suffice.

This has been a very brief summary of but one model of one theory of instruction. For additional, more detailed examples, see Reigeluth (in press). The above-described kinds of knowledge—principles, models, and theories of instruction—prescribe the general components of the instruction that is to be developed; and they comprise the scientific knowledge base that is increasingly being utilized by instructional developers. As the quantity and quality of this knowledge base continues to increase, its usefulness to, and degree of utilization by, instructional developers should continue to increase.

Scientific Process For ID

It was mentioned above that the scientific process for ID can be observed in the form of development models and procedures. The observe-hypothesize-test components of any scientific process are usually referred to as (1) front-end analysis, (2) instructional strategy prescription, and (3) formative evaluation. *Front-end analysis* identifies and observes the universe of important factors for designing the instruction, such as learner characteristics, learner and societal needs, and the available facilities. Next, with the aid of the knowledge base of instructional principles and procedures, a specific solution to the instructional problem is hypothesized. The hypothesis, or *strategy prescription*, is then implemented and tested on a small scale to check its validity through *formative evaluation*. Hence, the scientific process of observe-hypothesize-test has already been widely adopted for use in the development of instruction.

Knowledge about the scientific process in ID exists on two levels: (1) whole *models*, which list the steps a developer should follow from beginning (front-end analysis) to end (formative evaluation), and (2) limited *procedures*, which list the steps a developer should follow for one part of the whole process (e.g., a needs analysis procedure). For purposes of this discussion, brief descriptions of several so-called whole models should be sufficient. Extensive recent reviews of such models and selected procedures will be mentioned for readers interested in more detailed information.

Whole Models

Two of the most pervasive and, to date, comprehensive development models have been designed and implemented in markedly different contexts. One, commonly referred to as the IDI (Instructional Development Institute—see Twelker, et al., 1972) was initially created by a consortium of academic programs in the late 1960's to guide the training of development teams within elementary and secondary schools, as well as to guide relatively comprehensive development endeavors once the teams were trained. In addition to extensive federal support for the creation of the model and its accompanying training materials, considerable numbers of training workshops have been conducted around the country and outside of the United States. The materials have also been translated culturally and linguistically for use by local professionals in developing countries. The consortium, now called the University Consortium for Instructional Development and Technology, continues to revise and repackage these materials as needs and opportunities arise.

A second development model, also amply supported during its formative stages, is fondly referred to by users of its entire five volumes as the ISD, or Interservice Procedures for Instructional Systems Development (Branson, et al., 1975). Originally designed to provide official procedures and techniques to be used in the development and conduct of U.S. Army training, it eventually was adopted by the Interservice Committee for Instructional Systems Development as the official guide for the Air Force, Marines and the Navy as well.

Two reviews of these and other I.D. models have been published (Durzo, Diamond & Doughty, 1979; Andrews & Goodson, 1980), and a third is now in final editing stages (Gustafson, in press). Each review employs a different analytical and conceptual perspective, but all in one way or another address the artistic-empirical-scientific issue. In general, both models provide useful and substantive guidance for developers, but neither deals adequately with the strategy prescription component required to make them exemplars of the scientific approach to ID.

Limited Procedures

Embedded within many comprehensive development models, and more often, touted separately as procedural solutions to more limited development-related problems, are a wide variety of design, development and/or evaluation activities. As in the case of whole models, these range from the "If it feels good, do it" perspective to the "Ounce of prescription vs. pound of cure" rationale. Of course, the more middle range "If at first you don't succeed . . . " empirical paradigm is amply represented as well. Three of these limited-procedure areas merit brief comment here. They include various analytical techniques, prescriptive design theories, and formative evaluation procedures. Prescriptive approaches were addressed in the preliminary sections of this article and are again identified here to emphasize their place and role in the entire development process. The other two, familiar at some level to us all, are briefly discussed below.

Analysis Procedures

Of the many analytical procedures available to the developer, at least four show promise of contributing to a science of development. All typically are employed during the early stages of the design process. The first of these, *needs analysis*, enjoys considerable favor with external funding agencies, since the results usually are used to help justify (or at least decide upon) what is to be done. Approaches advocated by such authors as Coffing and Hutchinson (1974) and Kaufman and English (1979) and reviewed by Witkin (1977) present empirically-based procedures driven at least partially by management or organizational theory with a heavy systems emphasis.

A number of different procedures have been developed for conducting a **task analysis.** Gagné's (1968) hierarchical task analysis procedure is widely used and misused. The most popular alternative (or complement) is the information processing approach to task analysis, including path analysis, which is available in various forms (Landa, 1976; P. Merrill, 1978; Resnick, 1973; Scandura, 1973). For tasks that are difficult to proceduralize, Begland (1981) has developed a "soft skills" analysis procedure. And Reigeluth and Merrill (in press) have attempted, with support from the Army's Training and Doctrine Command, to integrate all of the above task analysis techniques into a single procedure called the Extended Task Analysis Procedure. Many of the information-processing people have also developed learner analysis procedures for assessing learner entry behaviors in relation to the analyzed task behaviors (see e.g., Landa, 1976; Scandura, 1973).

Content analysis is less common than task analysis and differs from it in that it usually entails analyzing non-procedural knowledge. Merrill (1973) has argued that content exists independently of the level of behavior at which it may be used. Gagné (1974) discusses this distinction in terms of performance vs. stimuli. Several content analysis procedures have been developed. Although seemingly similar in intent, these approaches are very different in practice and subsequently in results. Examples of these approaches include suggestions by Gagné (1974), Pask (1975), and Reigeluth and Merrill (Reigeluth, Merrill, Wilson, & Spiller, 1980; Reigeluth & Stein, in press). For an excellent review of task and content analysis methodologies, see Gibbons (1977).

Formative Evaluation

The 1960's also fostered the initial practical procedures of developmental testing and subsequent formative evaluation approaches. Although literature abounds describing the rationale and procedures in this area, reviewers (e.g., Baker & Alkin, 1973; Dick, 1980) are consistent in their suggestions that very little is known about the actual effectiveness of these techniques. Emphasizing prototype review, small group and field-based validation, proponents appear to never get beyond the "trial and error" rationale as defense. Therefore, we are left with a piece of the instructional development process that is largely art and trial-and-error.

This may surprise some true believers since evaluation has traditionally enjoyed the status of science. Evaluation does employ scientific investigation methods as evidenced by the research skills usually demanded of an evaluator. These skills include: research design, data analysis, statistics and sampling theory. But evaluation only employs the *look* of science. It is not a science in and of itself. If instructional science is to attain the precision of other hard sciences, it must produce a procedural and theoretical knowledge base for evaluation so that the scientific process of instructional development can move one more step beyond art and trial-and-revision.

Until that day comes, we must make the most of what science currently has to offer, filling in the remainder with our individual genius and empirical scrutiny.

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ness and industry to support the ideas presented. In general, the content of the book is very basic and provides an easy to follow treatment. The text emphasizes and justifies the importance of planning and structure in teaching. Case studies are effectively used to illustrate the parts of a lesson.

The author presents a new distinction between assessment and evaluation, indicating that assessment is concerned with people and evaluation is concerned with programs and courses. An excellent, helpful section on memory describes how to use knowledge about memory and forgetting to improve learning. The concept of mastery evaluation is presented and well-explained. Techniques for reducing paper work associated with instruction are described.

I can highly recommend *Instructional Techniques* as worthwhile reading for anyone in the human resources development field whether academic or business/industrial. The book is a potential text for a beginning instructional development course, but there are several others on the market which have proven successful for this purpose. All in all, it's worth reading and there are some gems of wisdom and helpful techniques to be gleaned from its pages.

Plying Your Craft

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Computers In Training—A New Track

Previewing at the 1982 annual NSPI conference in San Diego will be a new track to provide information regarding applications of computer technology to training. Presentations, panels, project reports, and discussions will focus on terminology, application, implementation, personnel support evaluation, and new technological development. Sessions will be selected to represent novice, experienced, and advanced practioner levels.

Project Reports

Project reports will consist of short seven-minute reports dealing with the use of computer technology in training situations. Roundtable sessions will allow attendees to have discussions with leaders in the field of computer-based learning.

Presentation Session

Presentations in these sessions will be more in depth and will last approximately 20 minutes each. The presentations may cover any aspect of the use of computers in training.

Emerging Technology

Emerging technology sessions will provide attendees with a review of developing technology and some insights into its potential upon training.

Review of Delivery Systems

Attendees will review the characteristics, advantages and disadvantages of several microcomputer systems. Attendees will also hear a panel of users discuss their likes and dislikes of various systems.

Persons interested in presenting or learning more about this new track should contact Glenn Head (303) 696-1346.

Some Sources Of The Art

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the complex, interactive functioning of so-called "variables." They assert that dissecting the real world into a few artificial variables merely results in the unreal. They are inclined to agree with Cronbach (1975) about the futility of attempting to store up generalizations. They see instead fragile principles that deteriorate in the light of a different population, setting or time. It is not difficult to see how developers holding this view of science would tend to focus upon those instructional decisions made without reference to scientific principles. They see a wide gap between the characteristics of instruction based merely on the dictates of science and those of excellent instruction. Science gets them only part of the way to effectiveness and will never be able to bridge the remaining gap.

So, in reconciling divergent views of ID, one instructive metaphor may be the proverbial water glass that was at once half empty and half full. Imagine an algorithm providing a total prescription for instructional excellence; the developer as scientist focuses upon the part that is now completed, the developer as artist upon the part that is missing. The scientist looks forward to its completion; the artist knows it will never be so.

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