Aptitude Versus Content-Treatment Interactions

Implications for Instructional Design

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Abstract. Interest in adapting instructional methodology to accommodate individual learner characteristics has been stimulated by the recent popularity of aptitude-by-treatment interaction research. While relevant to a descriptive theory of learning, ATI has failed to provide an adequate conceptual or empirical basis for a prescriptive set of adaptive instructional designs. The validity of adaptive designs as a focus for interaction research is questioned. Based upon cognitive task analysis and content analysis, the search for content-treatment interactions and their applications to instructional development should make adaptive designs more feasible, efficient, and consistent as well as developing important cognitive skills that may be short-circuited by learner-adaptive designs. Examples of research-based content-treatment interactions are provided.

Task Analysis
At the heart of the instructional design process is the practice of task analysis. The practice includes analyzing goal states in terms of the prerequisite and component learner behaviors that, if properly sequenced, lead predictably to some pre-stated terminal criterion. Emerging to preeminence with programmed instruction, task analysis provided the sequence for shaping the learner's behavior to produce the terminal objective. Although Davies (1973) identified six types of task analysis, the predominate method that has been employed is based on behavioral analysis. In planning for instruction, behavioral task analysis specifies the order of prerequisite capabilities (learning structure) that will most efficiently yield the prescribed terminal behavior (Gagne, 1970). Learning is conceptualized as associative and cumulative. Task analysis has sought to facilitate vertical transfer up the behavioral hierarchy, that is, to facilitate the acquisition of a series of approach behaviors.

The emergence and application of learning theory derived from cognitive psychology to instructional design has shifted the focus away from behaviorally oriented task performance specifications and hierarchical sequencing. Attention is now being focused on the internal information processing requirements of information acquisition (Low, 1980). Analysis of instructional tasks in terms of formal psychological models is the newest application of cognitive psychology to instruction.

Cognitive task analysis makes a different set of assumptions about learning than do strictly behavioral approaches. It seeks to identify and order the internal information processing operations required to perceive, store, access, and operate on knowledge. Resnick (1976) has constructed a cognitive model of task analysis—rational process analysis. Rational task analysis, an amalgam of Gestalt, cognitive, behavioral, and information processing theories, describes in detail an "idealized" set of operations derived from subject matter structure, i.e., content. These operations and the psychological abilities necessary for their performance are analyzed and sequenced for optimal performance. It functions as an information processing model for the accomplishment of cognitive objectives (Greeno, 1976) and the consequent knowledge acquisition. The key to cognitive task analysis is that in any learning situation, a description of the psychological operations must include representations of the specific content and the operations on it by the learner (Gregg, 1976).

If the product of learning is the arrangement of ideas in an individual's cognitive structure, Wildman and Burton (1981) recommend that cognitive task analysis should consider existing cognitive structure and content structure as input variables and the appropriate sequence of internal processes necessary for constructing the appropriate cognitive structure in the learner, namely accretion, restructuring, and tuning (Rumelhart & Norman, 1978). This is a process that can be accomplished rationally (analytically) or empirically (Winn, 1978). The designer must understand the structural relationship between concepts that form the content, i.e., content structure, developing designs that replicate that structure in the learner's cognitive structure (Wildman, 1981). Content structure analysis requires the application of rational techniques of task analysis. The most popular methods for performing rational task analysis, active structural networks (Norman, Rumelhart, and LNR, 1975) and digraph analysis based on the theory of directed graphs (Harary, Norman, & Cartwright, 1965; Shavelson, 1972), seek to map the knowledge structures or schemata that exist in memory or in prose respectively. Shavelson extended the techniques suggested by Harary et al. to empirically compare the content structure of a passage with the resulting cognitive structure developed in the learners.

Understanding how to structure content is ultimately predicated on how we represent knowledge in memory. Most contemporary conceptualizations are based on schema theory (Rumelhart & Ortony, 1977), which conceives of memory as a cognitive network of schemata or internal representations of interrelated concepts. These schemata have variables and represent concepts at varying levels of abstraction which embed within each other. As Winn (1978) suggested, designers engaged in
task analysis need to concentrate on the process of learning and the product and structure of knowledge as well as the task being performed. Systems should focus on designs that will facilitate the construction of appropriate cognitive structures. The underlying assumption is that subject matter structure provides an important basis for sequencing and synthesizing instruction (Reigeluth, Merrill, & Bunderson, 1978).

Cognitive or information processing task analysis has yet to be widely implemented because the necessary technology has yet to be developed (Wildman, 1981). This brief comparison of task analysis approaches is intended only to establish the conceptual groundwork for comparing two approaches to instructional design, the first based upon learner analysis and the second on subject matter analysis, another form of task analysis cited by Davies (1973), but rarely implemented.

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Learner Analysis

According to a recent survey of instructional design models, over two thirds of the models contain some method for assessing learner attributes (Andrews & Goodson, 1980). A review of those would reflect little consistency in what learner characteristics should be assessed or what implications that data should have for the design of instruction.

Interest in learner analysis evolved in the sixties as a complement to task analysis. Three primary purposes for collecting data were identified:
- as criteria for selection to an instructional sequence
- as a measure of prerequisite ability for placement purposes
- as a method for adapting instruction to the learner and vice versa using differential assignment (Schwen, 1973).

The first type of learner analysis was not generally in the domain of the instructional developer; rather it has been employed for making admission decisions based upon the predictive ability of the measure. The assessment of prerequisite knowledge was a function of the behaviorally oriented task analysis procedures prominent at that time. The latter, based on the emerging aptitude-treatment interaction research paradigm, considered a range of learner attributes for making decisions related to differential assignment of learners to treatments. Not only were achievement-related abilities being compared with instructional methods, but also specific personality traits, cognitive styles, and information processing and coding strategies (Snow & Solomon, 1968). A new dimension had been added to task analysis procedures. Fueled by the revolution in learning theory produced by differential psychology, analysis of individual differences and their interaction with design strategies were added to the armamentarium of the instructional developer.

Aptitude-Treatment Interactions

The concept of aptitude-treatment interactions (ATI) is one of the best known in the educational research field today. Its genesis dates back a quarter of a century, when Cronbach (1957) used a correlational approach to relate individual differences and experimental approach. Cronbach and Snow (1969) laid the groundwork for contemporary ATI research by suggesting methodological and conceptual guidelines for its conduct. In essence, ATI is a methodological paradigm that seeks interactions between alternative aptitudes (Cronbach & Snow, 1969), attributes (Tobias, 1976) or traits (Berliner & Cahn, 1973) and alternative instructional methods. Although these terms make different assumptions about inclusiveness, aptitude is the most common designation. Aptitudes refer to any personological variables, including general intelligence, prior learning personality, or cognitive styles, on which individuals differ and that predict performance from instructional treatments. Treatments consist of the structural and presentational properties of instructional methods that might be expected to interact with the learner characteristics being analyzed. Interactions occur between aptitudes and treatments when individual differences in the former predict different outcomes from alternative treatments. That is, instructional treatments may facilitate learning or they may inhibit learning, depending upon their structural characteristics.

Generalized regression analysis is normally used to produce slopes by regressing the dependent variable (outcome variable) on the aptitude variable. Statistical differences between the slopes (normally assessed by heterogeneity of regression) indicate either an ordinal interaction or a disordinal interaction, which most researchers believe to be the more meaningful. Both have implication for instructional decision making as a guide for assignment of learners to treatment condition.

Cronbach and Snow (1977) suggest that learners with aptitude scores greater than that adjacent to the point of intersection be assigned to one treatment, those with lower aptitude scores to the other, to maximize learner output. Such an assignment may lack the reliability that can be effected by determining the regions of significant differences of outcomes (Berliner & Cahn, 1973). That is, differential assignment to Treatment A is reliable for aptitude scores somewhere above the intersection of regression lines. Conversely, the region-of-significance for assignment to the alternate treatment is somewhere below the intersection. A number of statistical techniques exist for determining these regions (Cahn & Linn, 1971; Pothoff, 1964; Seral & Levin, 1980).

Extensive reviews of ATI research (Bracht, 1970; Berliner & Cahn, 1973; Cronbach & Snow, 1977) have found what Bond and Glaser (1979) indicate are "mostly A and T with not much L." The lack of consistent support for the ATI hypothesis has resulted from the weak conceptual grounding and deficient methodology employed in many of the studies reviewed. Small N's, abbreviated treatments, specialized aptitude constructs or standardized tests,
and a lack of conceptual or theoretical linkage between aptitudes and the information processing requirements of the treatment have often resulted in failure to produce interactions. The following review of these problems is largely theoretical. While a major goal of aptitude-treatment interaction research has been the derivation of explanatory principles concerning the nature of instruction (Salomon, 1972), most studies have focused on the predictive relationships of aptitudes in the differential assignment of subjects to treatment. ATI have often been empirically conceived, insensitive to the belief that “understanding of the psychological processes of a specific learning task is prerequisite to the development of a theory on the interaction between traits and treatments” (Berliner & Cahen, 1973, p. 59).

The absence of a adequate conceptual basis for selection of aptitude variables for research has often resulted in a shotgun approach. For instance, Seidel (1973) administered 27 instruments measuring 35 variables in an effort to generate significant ATI. Probabilistically, he found a few. The need for better conceptualization of treatments, which considers the information processing requirements called upon by the treatments, is one of the most persistent problems in ATI research (Fagan, 1979).

Recent ATI research models have sought to overcome this problem. If ATI research is to be fruitful, DiVesta (1975) claimed that “the theory underlying TTI research must consider the cognitive processes assumed to be correlated with the traits and/or processes induced by the treatments” (p. 189). This assumption led to his search for TTI’s (trait-treatment-process interactions). Snow (1977b) promoted the use of two complexes of aptitude variables, the first of which concerns general mental ability, which has a well established relationship to learning but is too vague to be of use to ATI research. His G-complex consists of crystallized (conceptual-verbal) and fluid (reasoning/non-verbal) intelligence (Cattell, 1971) expanded to include general visualization intelligence (Horn, 1976). Yallow (1980) recently confirmed the interaction of these with verbal vs. figural elaboration in instruction. Measures of another factor-derived intelligence model, the structure of intellect (Guilford, 1967) were compared with figural-inductive and symbolic-deductive instruction, producing no significant ATI’s (Eastman & Behr, 1977), perhaps because Guilford's model is susceptible to pitfalls of differential methodology because of its failure to specify processing strategies (Sternberg, 1978).

Some of the most significant recent work with intelligence has been conducted by Sternberg. Using componential analysis (Sternberg, 1977), he has developed a theory of human reasoning (Sternberg 1978), which he used to match treatments to information processing strategies (spacial and algorithmic) for teaching linear syllogisms. When no aptitude-strategy interactions resulted, the aptitude groups were reformulated on the basis of models of response latencies, which then produced aptitude-strategy interactions. Recent research has been successful in identifying processing components of intelligence and relating them to aptitudes measured by traditional psychometric instruments. These provide a theoretically rich model for future ATI research.

Snow’s (1977b) other general aptitude complex focused on motivation and anxiety. The complex consisted of achievement via independence, achievement via conformity, and anxiety measures as being the most relevant personality variables to learning. A series of long-duration, classroom based studies have confirmed the usefulness of the complex in producing consistent univariate and bivariate ATI’s (Peterson, 1977; Peterson, Janicki, & Swing, 1980).

Some of the most consistent theoretical linkages between aptitudes and treatments have been suggested by Salomon (1979), who applied his own heuristic model for generating ATI hypotheses (Salomon, 1972) in a series of studies which modeled the information processing characteristics measured by the aptitude variables in his treatments, producing a number of meaningful ATI’s. Even though current ATI research has refocused attention on the processing characteristics of aptitudes and the cognitive structural characteristics of task and achievement (Snow, 1980), much of the existing ATI research base is not generally theoretically based. Rather, hypotheses are still frequently a posteriori, using stepwise procedures to identify the most fruitful. As ATI research based upon coherent and consistent theoretical grounds continues to amass, this deficiency may no longer restrict its application to instructional design, which is also embracing a more cognitive orientation (Low, 1980; Wildman & Burton, 1981).

2. ATI results are inconsistent.

“In countless studies, intelligence has emerged as the strongest and often the only predictor, sometimes even when it wasn’t being measured.”

Tobias (1981) concluded from several studies that ATI were generally inconsistent. Significant interactions are offset by more non-significant treatment differences. Very few replications of ATI research have yielded significant interactions. In fact, many replications have reversed the findings of the previous study or were followed by non-significant differences. Tobias has also found that different researchers evaluating the same aptitudes or treatments produce dissimilar results. When ATI’s do occur, most are not strong, i.e., they are ordinal and therefore not useful for differential assignment. Results are often isolated and artificial.

These poorer, fashionable studies that are rarely replicated don’t employ generalized aptitude constructs and employ short duration treatments ofen resulting only in higher order interactions which are uninterpretable (Snow, 1977b). When meaningful conceptually based aptitudes and treatments are employed, replications may occur (Peterson, Janicki, & Swing, 1980). It is recognized that ATI is no more fragile than most areas of educational or social science research.
It is only its applicability to a prescriptive design science of instruction that is being questioned here.

3. **ATI results lack generality.** In addition to the lack of consistency, most ATI results cannot be generalized to similar populations or across time. They lack external validity. Many ATI studies are not classroom-based. When they are, class effects often interact with treatments or aptitudes. Within-class regression analyses have nullified significant grouped (between class) aptitude-treatment interactions (Brophy, 1979; Cronbach & Snow, 1977; Green, 1980; Gustafsson, 1978). The social context of the classroom plays an important role in learning, although it adds another order to the interactions. The interactions both among and between aptitude variables and instructional conditions are so complex as to render generalization impossible (Snow, 1977a). It is impossible ‘to store up generalizations and constructs for ultimate assembly into a network’ (Cronbach, 1975, p. 123). A generalizable theory of aptitude-treatment interactions is not possible. Learning is too context-specific. At best we can hope to develop local instructional theories related to local instructional situations concerned with small portions of the curriculum and small segments of the population (Snow, 1977a). Snow concludes that it is possible, through continuous, systematic, formative evaluations of ATIs over time in a given place to generate a dynamic instructional theory for that place that could not generalize to another.

ATIs do not appear to generalize over time; however, long term, realistic studies suggested by Cronbach & Snow (1977) are capable of producing some interactions. Hickey (1980) found in a semester-long study that internal, high general reasoners benefitted from low instructional support. Unfortunately, this type of longer term interaction is subject to instability over time. For instance, over a sequence of four units, Burns (1980) found that crystallized intelligence (perhaps the best general intelligence construct available) was consistently correlated to performance, yet all other aptitudes fluctuated over time. Burns concluded that the time-dependence of aptitude-learning relations is mainly reflective of the fluctuations in content requirements over time, method requirements being more consistent. Treatment effects may also change over longer periods of time, suggesting what Cronbach (1975) referred to as Decade X Treatment interactions. It seems that ATIEffects can only be generalized to individual classes in a specific locale during a finite period in history.

4. **ATI also interact with task content characteristics.** To further mitigate against generalizability, ATI also interacts with processing characteristics of the criterion task to produce complex performance differences (Rhett, 1974). He found that error rates were higher but response latencies shorter for impulsive learners, with opposite prior learning (Tobias, 1976) and anxiety (Tobias, 1977) do exist, their relative contributions to learning are normally less than mental ability (intelligence) and therefore probably less cost effective. It is doubtful that significant attributes would be of equal importance to instruction in different areas (Tobias, 1976). Snow's work has indicated mental ability is best represented as a complex (see No. 1 above), the sub-components of which may differentially interact with treatment. All of this might suggest

“It is impossible to adapt reality, to break it down and synthesize it into a different form for each learner, as an ATI-based paradigm suggests. Such an approach is atomistic.”

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Trends in ATI research

The methodological and conceptual problems that have plagued ATI research were explicated by Cronbach and Snow (1977). Trends in research indicate that at least some of the problems are being addressed:

- bivariate and multivariate regression on meaningful complexes of aptitude variables
- longer term, larger scale studies
- laboratory-based studies to isolate and test specific processes operating in ATI (Snow, 1978)
- theoretically oriented methods for deriving aptitude factors
- concern for social, contextual variables affecting ATI

If current efforts are successful, in a decade it may be reasonable to summarily reject most ATI research conducted before the mid to late 1970's, depending upon the reoriented research methodology of the 80's for an accurate picture of learner-environment interactions. At such a point, the previously cited deficiencies in the ATI research base would no longer exist.

**ATI Design Models**

ATI is conceptually based in differential psychology, which focuses on the interactive effects of personological and environmental
variables in behavior. Individual differences identified by this field have obvious implications for the design of individualized systems of instruction. "All attempts to individualize instruction, it turns out, rest explicitly or implicitly on some kind of ATI idea" (Snow, 1977c, p. 23). The assumption has been that ATIs that are conceptually coherent and can be consistently generated provide guidelines for accommodating the individual differences they assess. However, the meaning of the word accommodate has been understood."

One of the most prominent adaptive instructional design models pro- mulgated so far is by Parkhurst and McCombs (1979). Believing that "the ATI concept is best applied, not in isolation but as an integral part of the dynamic decision-making instruction environment" (p. 33), they developed a rationally and empirically-based ATI instructional design model. The major steps of the process include:
1. Establish main track (best method) modules.
2. Establish student characteristics (related to criterion performance) data pool.
3. Evaluate main track performance for excessive failure rates/variance.
4. Develop alternative modules based upon predictor/criterion variable relationships.
5. Evaluate alternative modules in terms of cost effectiveness.
6. Implement differential assignments of students to alternative modules and monitor.

The model advocates consideration of a broad spectrum of predictor variables, including cognitive skills, achievement motivation, personality, and achievement characteristics. Its effectiveness has been verified in reducing learning times and improving test scores (McCombs, Note 2) using treatments that generated significant ATIs (McCombs & McDaniel, Note 3). The key to applying this design resides largely with empirically identifying relevant cognitive and effective variables for each lesson in the design treatments (McCombs & McDaniel, 1981). Adaptive designs, such as those researched by McCombs, tend to be more effective at the microadaptive level and be particularly amenable to computer-based delivery (see also Tennyson, 1980; Tennyson, Tennyson, & Rothen, 1980). A point of concern with the Parkhurst/McCombs design model is its reliance on a "best method" with alternative mediation or modeling (compensation) of deficient skills. Are the assumptions substantively different than those for traditional instructional approaches?

This engenders perhaps the most fundamental yet least considered issue related to adaptive instructional designs—just what are we trying to accomplish? Shuell (1980) asked if we are trying to produce academic equality, eliminate individual differences, or maximize all learners' outputs. These are mutually exclusive ends. The latter goal, for instance, would expand individual differences, thereby reducing academic equality. Can we afford the social ramifications of reducing academic equality. On the other hand, should we provide unequal opportunity by matching instruction only to the needs and requirements of a few?

Most adaptive instructional designs based on ATI's employ one of three types of matches: remediation of learner's deficiencies, compensation for deficiencies by modelling cognitive behavior, and preference, capitalizing on learner strengths (Salomon, 1972). Although these were intended only as heuristics for generating ATI hypothesis, they have formed the basis for the matching model of instruction. Additional methods for matching methods to learners, based on individual differences and the existence of aptitude-treatment interactions, included combination matches (combinations of above) and challenge matches, in reality mismatches that challenge the learner to acquire necessary but currently deficient mental skills (Messick, 1976). Based upon this matching premise, Ausburn and Ausburn (1978) have proposed an approach to instructional design that compensatorily matches instruction to differences in learners' cognitive styles. The first step, task analysis, determines the stimulus-transformation requirements of the task. The second step determines, based upon assessment of learning styles, the group of learners deficient in the processing skill for whom treatment will need to supplant (compensate) the required cognitive process.

Finally, designers must determine how to structure the treatment so that it will supplant that ability, that is, take the learner in Step 2 to the goal stated in Step 1. Predicated only on Salomon's supplantation hypothesis, which has been empirically supported, this design model ignores Salomon's belief that mental skills may be, depending upon individual differences, more successfully cultivated by calling-upon rather than supplanting the processing operation (Salomon, 1977). Not all learning processes need
supplantation, so uniform application of this model would be insensitive to learner needs.

An alternative matching model of instruction that has been extensively investigated is based upon Conceptual Systems Theory (Hunt, 1975; Hunt & Sullivan, 1974). This model focuses on individual differences in social cognition within a developmental framework. Based upon person-environment interactions, it seeks to match learner's conceptual level (degree of cognitive complexity) with the degree of structure provided by the environment (contemporary matching). While Conceptual Systems Theory is one of the most coherent and comprehensive personality theories available, only a small group of studies support the contemporary matching hypothesis (Miller, 1981) and many more do not. Four major problems appear to militate against an ATI-based instructional design model in ATI research, whether it seeks to adapt instructional treatments or match learner characteristics.

The attempt to accommodate individual differences identified by ATI research in instructional designs is a noble, egalitarian idea, albeit a less practical one. A CTI approach to design is inherently more practical, cost-effective, consistent with theory, and productive.”

1. The conceptual and methodological problems have produced inconsistent and ungeneralizable results. Generalizing procedures from weak data would only produce weak designs. While the very recent ATI research appears to have rectified many of the problems that plagued earlier research and are now producing consistent results, there doesn't yet exist a large enough data base to provide the foundation for an instructional design model based on ATI results. This situation may change in the future.

2. Accommodating individual differences resulting from ATI is not feasible. The logical implication of ATI research is to provide for individualized programs of instruction. The complex nature of higher order interactions that inevitably occur when the range of significant predictor variables are considered, make multivariate individualization impossible.

3. Instructional designs should not necessarily provide learners instruction in their preferred mode. Practitioners often confuse the prescriptive purpose of an ATI form of learner analysis by inferring that what is sought are interactions between learner preferences and treatments. Others have even promoted it as a design strategy. Merrill (1975) recommended that designers go beyond ATI by allowing the learner to control instruction.

Learner control is premised on two assumptions: (1) All learners know what is best for them at any given time in the instructional sequence, and (2) they are capable of acting on this
knowledge (Snow, 1980b). The evidence doesn’t support this notion. In fact, Clark (1980) found from reviewing a number of studies that students prefer the method of instruction from which they learn the least. For example, high ability learners prefer more structured, directive instruction but benefit most from non-directive methods. A number of micro-adaptive structural programs that sought to accommodate prior knowledge (Ross & Rakow, 1980; Seidel, 1973; Tennyson, 1980; Tennyson & Rothan, 1980) have failed to support the effectiveness of learner control of instructional sequence, especially for more positive results. The implication is that content structure, especially for concept acquisition tasks, should be used to determine instructional strategy. The case for learner control of instruction requiring learner self-determination, autonomy, and responsibility simply has not been supported (Snow, 1980b).

The combination of these factors, but especially the feasibility issue, seems to reject the advisability of adaptive, learner-oriented, ATI-based systems for individualizing instruction. Within the decade, the ATI research base and computer-based instructional systems may evolve to the degree where such instructional systems are possible. The fact that only a handful of research-based agencies (most of which are military) are even experimenting with and attempting such designs indicates that widespread acceptance is unlikely. A more feasible, theoretically justifiable alternative will now be presented—content treatment interactions.

Content Treatment Interactions

Task analysis based on the processes required for assimilating and using information is necessarily content specific. Learning content requires a sequence of mental operations. Certain dependency relations between content constituents are necessary to consider when sequencing learning (Kingsley & Stelzer, 1974). These relations can be graphed to form a general cognitive network which is then related to tasks derived from objectives to form the subject matter structure.

A component analysis of the operations implied by any content, therefore, is necessary to select and sequence content (Merrill, 1973). It follows that the structure of the treatment will affect the cognitive operations required to learn that content. The manner in which treatment characteristics interact with content characteristics implies a design model with a different focus than that implied by aptitude-treatment interactions—one which uses task analysis based upon subject matter structure (Davies, 1973).

If we assume that subject matter structures provide an important basis for how to sequence and synthesize instruction (Reigeluth, Merrill, & Bunderson, 1978) and that task analysis should describe the optimal internal mental processes of the learner, based upon subject matter structure as suggested by cognitive task analysis, then designers should be seeking instructional treatments (sequences, codes) that simulate those processes. Just as ATI assumes that no treatment is appropriate for all learners, a content-treatment interaction approach (CTI) assumes that no particular treatment modality is appropriate for all content. Since subject matter is defined by different types of content (facts, concepts, principles, problems) calling on different mental processes, instructional treatments coded or sequenced to simulate those processes must also differ.

"Rather than shaping the treatment to individual differences in processing, why not shape the processing of individuals? It can be done far more efficiently."

Instructional designers need to know how those processes vary and what the implications of those variances are for instruction. The purpose would be to design sequences of instruction with structural and coding properties as isomorphic to the mental processes required for learning material at different content levels. A CTI approach is premised on differences in cognitive processes required by content that predict different outcomes from alternative treatments. In a number of studies, Salomon (1972, 1974, 1979) has found that instructional treatments that model the internal processing requirements of the task result in superior learning. In an exemplary study, Mayer (Note 4) found significant disordinal interactions between texts with and without advance organizers and degree of transfer required by the test and degree of organization required by the materials. Organizers facilitate far transfer but actually inhibit near transfer of learning. They facilitate learning from randomly organized text but inhibit learning from logically organized materials.

Learners should be assigned to the treatment that best simulates the content processing requirements which result in most efficient learning. The most obvious initial criticism of such an approach is that individuals don’t all process information alike, so why instruct them all alike? Three reasons exist.

First, because content process analysis has indicated that a certain sequence of operations are necessary for learning a specific type of content and that a particular sequence, as represented by the treatment, is the most efficient combination of processes.

Second, human learners are very capable of adapting to specific task requirements, even though distinctive, individual learning styles do exist (Rhett, 1972).

Third, entry level learners deficient in certain mental operations will through appropriately structured
potentially infinite number of treatments to teach different learner types. Is it educationally feasible to adapt instruction to each learner? Rather than shaping the treatment to individual differences in processing, why not shape the processing of individuals? It can be done far more efficiently. It would be fatuous to assume that such designs would be completely impervious to individual differences or contextual differences as suggested Snow (1977a).

Valid and reliable empirical findings can only supply designers with heuristics for assigning instructional treatments to specific types of learners. Likewise, CTI is not being posited here as a design model. The results of research can provide designers with a cognitive model of information processing for specific learning tasks, which can be translated into treatments.

The remainder of the paper will review briefly instructional methods and principles that have exhibited content-treatment interactions or possess unverified potential. This list is not exhaustive. In essence, they suggest ways for sequencing and presenting instructional treatments based on content structure characteristics. The first two are macroadaptive component analysis strategies, while the next two are microadaptive (lesson-level) strategies. The final group of curriculum strategies are conceptual in nature.

Advance Organizers

Based upon subsumption theory (Ausubel, 1962a), organizers function to bridge the gap between what the learner already knows (present cognitive structure) and what the learner needs to know in order to learn. Organizers provide the ideational scaffolding for incorporating a new piece of information into a person's cognitive schema (Ausubel, 1963, 1968), i.e., they activate the appropriate existing schema in the learner so that new information can be readily assimilated.

Presented "at a higher level of abstraction, generality, and inclusiveness," good organizers are concrete models, analogies, examples, and higher order rules (Mayer, 1979a).

A recent meta-analysis of 132 studies indicated that organizers do in fact facilitate learning and retrieval (Luiten, et al., 1980), as well as transfer. The case for organizers more recently has been reconceptualized as assimilation encoding theory (Mayer, 1977, 1979a, 1979b), which states that meaningful learning is the reception of material into an existing assimilative context with the assumption that the learner will actively use that context during learning. Observed from this perspective, the use of advance organizers has generated several significant content-treatment interactions. Mayer (1979a) found that organizers interacted positively with materials that are conceptual in nature, unorganized, and likely to be unfamiliar to the learner.

Organizers were more effective when they provided a high level context for learning and when the cognitive task was breadth of transfer and not retention. The results of a series of his own studies supported assimilation theory (Mayer, 1979b) and suggested interactions of organizers with learning that require far transfer as opposed to near transfer, discovery learning, application of higher order rules, integration of premises, and the use of linear reasoning. Non-organizer groups tend to focus on detail rather than relating to conceptual units. All of these results suggest the application of organizers and the consequent restructuring of learning materials based upon content analysis, not learner analysis. The research base on advance organizers makes them probably the most readily implementable content-structured learning approach.

Elaboration Theory

Conceptually related to advance organizers is the elaboration theory of instruction. Elaboration theory (Reigeluth, 1979) prescribes a sequence of instruction that provides the learner with an overview (epitome) of the subject and then elaborates one part of the subject to a predefined level of detail. A review includes the epitome and the part just elaborated. Each first level elaboration (only slightly more specific than the overall epitome) is further elaborated to a second level of detail, which is followed by a summary leading to an expanded epitome on that elaboration, and so on. The primary structure of elaboration theory consists of a series of synthesis-analysis-summary operations (Merrill, Wilson, & Keley, Note 5).

This top-down, general-to-detailed sequence of learning incorporates a fundamental principle from subsumption theory (Ausubel, 1968), progressive differentiation. The theoretical basis for elaboration theory—which is not really a theory, but rather a group of organizing prin-
principles for instruction or "elaboration technology" (Mayer, 1981)—is schema theory. The learner is provided with a schema or framework for assimilating more specific material. The schemata or epíomes comprise a network for integrating and relating concepts, an internal integrative reconciliation process, since relationships between the concepts which form the structure of the content should be taught explicitly. Elaboration theory seeks to make the content structure obvious (Reigeluth & Merrill, 1979). A scheme combining elaboration theory and information processing analysis (P. Merrill, 1978) as a task analysis procedure is described by Reigeluth and Rogers (1980).

Although a paucity of empirical verification of the elaboration theory exists, content-treatment interactions similar to those for advance organizers could be inferred based upon the similarity in their theoretical background. Elaborated lessons would be expected to facilitate the learning of conceptually oriented material requiring transfer rather than recall. Rule using and discovery learning would also be expected to profit from the elaborated morphology provided by such instruction, whereas recall, near transfer and serial learning tasks probably would be inhibited by elaboration theory.

**Component Display Theory**

Component display theory (Merrill, Reigeluth & Faust, 1979; Merrill, Richards, Schmidt & Wood, 1977) has evolved over the past decade into a comprehensive theory (or technology) for designing, sequencing, and presenting instruction. It accommodates not only differences in tasks in its design but also considers content types. A set of principles and procedures are prescribed for determining the consistency between educational purpose, objectives, test items, and finally, presentation forms and the adequacy of each in terms of the inclusion of strategies, such as feedback, isolation, prompts, divergence, and matching. The application of these strategies to primary presentation forms varies by task level and content type.

As an instructional theory, it is premised on content x task x treatment interactions. The assumption is that instruction should be organized on the basis of the structural properties of the content and the nature of the interaction between content and the intellectual requirements of the learning task. It predicts that a particular combination of presentation forms will optimally produce learning (Merrill, Kowallis & Wilson, in press).

Such a prediction requires empirical support. In a series of validation studies conducted in real-world settings (Merrill & Wood, 1977) instructional procedures designed using component display theory did not produce significantly better performance or times-to-completion. However, in a post hoc comparison of competing organic chemistry texts, the book that achieved a higher rating on the basis of component display theory variables produced commensurately better student performance. Since component display theory is premised on such well-established principles of future validation efforts should probably confirm its efficacy as a content structural model of instructional design.

**Discovery Learning**

The popularity of the discovery approach to learning resulted from the advocacy of Jerome Bruner (1961), who promoted a classical, scientific method of discovery—inferencing from evidence, gaining insights, allowing students to organize information and later apply it to the solution of learning problems.

Early instructional designers working in programmed instruction reduced the discovery-expository dichotomy to testable constructs—RULEX (rule or generality followed by examples) and EGRULE (instances presented to induce rule) (Evans, Homme, & Glaser, 1962). The former represents an expository and deductive approach to instruction favored by Ausubel (1962b), and the latter, EGRULE, represents an inductive, discovery approach where the learner is required to infer the generalization from the common characteristics represented in the instances.

Despite a number of conceptual (lack of agreement on meaning of discovery) and methodological problems plaguing discovery learning research, some generally consistent conclusions can be drawn (Herman, 1969). Content-treatment interactions tend to occur with regard to the information processing requirements of the task. RULEX or expository instruction facilitates retention of material whereas EGRULE or discovery methods generally inhibit recall. Remote transfer skills, on the other hand, are facilitated by discovery methods and inhibited by expository (Guthrie, 1967; Worthen, 1968). Some form of intermediate direction (guided discovery) tends to produce superior results regardless of the dependent variable (Gagne & Brown, 1969; Kornreich, 1969).

The results of discovery learning research also provides a heuristic, based on a content-treatment interaction conception, for structuring and sequencing learning. Those tasks that entail application and transfer should require the learner to induce or discover the concept or principle defined by the subject matter. A sequence of instances with appropriate prompts can be presented to the learner so as to insure some success, a necessary ingredient to keep learners on task (Anderson & Faust, 1973). For recall of concepts or principles, an expository or RULEX approach is more efficient, as Ausubel proposed.

**Curriculum Development**

If all of this discussion of instructional methods sequenced and arranged by the content structure of the subject matter gives you the unsettling feeling of deja vu, its understandable. You were there—in the sixties, when curriculum theorists stressed the importance of the structure of the discipline (Bruner, 1960). The same underlying theories regarding organization of knowledge and its reflection in the learning curricula being homeomorphically reconstructed in the knowledge bases of learners is behind most of the approaches presented here. Content structuring from a curriculum point of view, however, does not begin with assumptions about human learning. That is, sequencing is not based upon principles of cognitive processing. Rather...

"Cognitive task analysis makes a different set of assumptions about learning than do strictly behavioral approaches."
organization of curriculum and materials is mostly based on characteristics of the knowledge being learned, not on characteristics of human learning. The attempt is to represent things the way they are.

To this end, Posner and Strike (1976) analyzed content structure, dividing it into five major classes including:

- World-related: the way things exist in the world
- Concept-related: organization of conceptual world into logical structure
- Inquiry-related: logic and methodology of discovery
- Learning-related: processes of human learning, including hierarchical prerequisite, prior learning, difficulty, development requirements (related to ATI concept)
- Utilization-related: social, personal, or career needs

These classes represent a broad range of organizational perspectives, many of which have been verified by a substantial body of human research. Their applicability in learning contexts have been tested over a number of years. Their intuitive value in sequencing instruction is doubtless. Since this paper elaborated from instructional design and task analysis, however, a lengthy review of these content-constructing principles exceeds page restrictions. Suffice it to say they offer the instructional designer a large number of plausible alternative hypotheses for sequencing instruction.

**Philosophical Analysis**

The final justification for a content-structural approach is philosophical, a consideration traditionally eschewed by researchers concentrating on behavior. If our theories/models won't stand the test of philosophical scrutiny, they perhaps should be discarded.

Content-treatment interactions are premised on the mapping of the structure of ideas represented in the subject matter onto the structure of knowledge in the memory of the learner exposed to that subject matter. This perspective makes certain assumptions about how the learner acquires knowledge. This perspective makes certain assumptions about how the learner acquires knowledge. It assumes a constructivist position that conceives of man as an organized entity that actively participates in the construction of known reality (Reese & Overton, 1970).

This epistemological distinction has generally eluded research in educational technology, with its rigorous application and sequencing of hierarchical patterns of behavior. Constructivism suggests that we reject such a closed system of ordering learning tasks and procedures into rigid hierarchies. Based largely on the work of Piaget and other structuralists, constructivism suggests that the assimilation of sense data stimulates internal, mental operations that organize that information into schema (a term first used by Kant just over 200 years ago). These operations in effect transform realistic sense data into mental constructs. Knowing reality is a process of constructing transformations that model reality (Piaget, 1970).

The approach to sequencing and synthesizing instruction suggested by content-treatment interaction is inherently constructive. Behavioral analysis, on the other hand, is inherently reductive, seeking to break down a constructive process like learning into its most rudimentary components. Polanyi (1958) has argued that the "comprehensive entity" that defines a person cannot derive merely from an analysis of the laws that apply to its behavior. All learning is surely related to knowing, which entails the internalization of ideas and their effects on an individual's personal identity.

The process of knowing, i.e., constructing personal models of reality, is also inherently individualistic. We all make sense out of the world differently. This should not imply that we can there is evidence (e.g., Alessandrini, 1981) that suggests learners will process information using their most effective strategy, regardless of the mode employed or control (directions) from the instructor. A more appropriate strategy would require the learner to interact with instructional materials and sequences to reconstruct or "re-present" it to his own knowledge structure (Sigel, Note 6). While cognitive psychology does not preclude the role of individual differences and by inference ATI, it is theoretically premised on the construction of knowledge rather than the analysis, reduction, and adaption of it.

In light of this conceptualization, a humanistic perspective would argue against peremptorily relegating learners to prescribed modes of learning. The categorization of humans, even along personological dimensions, and consequent assignment to modes of learning is inimical to the humanist's conception of man as a free and independent entity. Becoming an individual is experientially mediated and must be self-determined. While such ethical concerns are not in the normal purview of the instructional technologist, we cannot afford to practice our trade in a socio-philosophical vacuum.

**Conclusion**

As Olson (1976) concluded, we're a long way from a comprehensive theory of instruction necessary for adequately conceptualizing cognitive processes. Aptitude-treatment interaction techniques remain a valid research model that can, as Snow (1980) suggests, contribute to our understanding of these processes. Although improved methodology and more theoretically-based conceptualizations are producing more consistent and meaningful ATIs, available knowledge about ATIs is far from producing even locally generalizable models of design. CTI designs are more readily generalizable since distinguishable types of content (and to the cognitive process used in
acquiring them) are fewer and more readily classified than the number of personological and environmental variables that may interact anytime a given learner sits down (or stands up) to learn. By analyzing the interactions between treatment and content structure, designers are also contributing to the derivation of theories of instruction as well as producing "idealized" treatments that will lead more efficiently to learning. Summarily stated, instruction derived from cognition is content-specific.

Content treatment interactions, as developed in this paper, do not constitute a model of instructional design or research or the latest panacea for all learning problems, but rather provide a heuristic for researchers and designers. Just as ATI was not conceived as a theoretical rationale for educational research, neither is CTI. The structural properties of content and cognition that form the basis for CTI do represent an appropriate design rationale for instructional designers. The attempt to accommodate individual differences identified by ATI research in instructional designs is a noble, egalitarian idea, albeit a less practical one. A CTI approach to design is inherently more:

- practical
- cost-effective (another issue worthy of elaboration)
- consistent with theories of knowledge acquisition
- productive in terms of curriculum/product development.

Content analysis is a process only alluded to in many instructional design models and completely neglected in others. It is a design competency that is recognized in the new DID list of competency statements (Task Force, 1981), but how successfully are practitioners taught to "analyze structural characteristics of a job, task, and/or content?" If they have been, is such analysis normally transferred to practice? Content analysis is an essential process in instructional design that can be facilitated by a content-treatment interaction approach.

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