Part

V

INSTRUCTIONAL STRATEGIES

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GENERATIVE LEARNING CONTRIBUTIONS TO THE DESIGN OF INSTRUCTION AND LEARNING

Barbara L. Grabowski
Penn State University

28.1 INTRODUCTION

28.1.1 Learning or Instruction

Over the past 30 years, attention has gradually shifted from investigating the effects of the external, physical form *of instruction* to examining the internal processes of *learning* that are stimulated or induced by external stimuli. As a result, models and prescriptions for learning are founded on theoretical and empirical evidence about cognitive functioning, processes, and structure of memory. Using a learning foundation, designers develop a conception of the thinking that occurs within the learner and use this conception to guide the design of environments for learning. Instructional and learning environments both contain information; the key difference is who does what with that information. In a learning environment, the learners and their learning processes, styles, and goals take on prime importance. In an instructional environment, the roles of the learner and the instructor or designer are reversed. A learning environment is not devoid of instruction or an instructor, but rather the external stimuli simply take on a secondary role. In an instructional environment, the materials provided for the learners take on prime importance, with the assumption that learner characteristics have been taken into account and the belief that material design and presentation can affect learning.

The designers' beliefs about learning, that is, their epistemology, control their perception of their identity, roles, and responsibilities, which thereby affect whether a learning, an instructional, or a combination approach to design is taken (Grabowski et al., 2002; Jonassen, Marra, & Palmer, 2003). The locus for controlling learning (instruction or learner) has been debated throughout the history of the field, fueled by researchers' ability to gather evidence for their positions. The evolution of this understanding has been greatly influenced by the development of more refined research methodologies and advances in technology. Armed with new methods, designers, who hold the belief that both the learner and learning environments are of equal importance, that intentionality on the part of the designer *and* the learner is critical, are most likely to design promising instruction and learning environments that blend the extreme beliefs held by behaviorists and constructivists (Grabowski, 2002; Grabowski et al., 2002).

Generative learning theory, with its companion model, generative teaching, is one such area of blending whose theoretical foundation lies in neural research, research regarding the structure of knowledge and cognitive development, with a focus on selecting appropriate, learner centric instructional activities for the learner. This theory is one that combines the importance of learner and instructional intentionality. Bonn and Grabowski (2001) call generative learning theory the "practical cousin of constructivism." Perhaps it also provides a more complete perspective on learning, making it a "second cousin" to behaviorism. The theory blends our understanding of learners and design of external stimuli or instruction.

This chapter defines generative learning and its foundation, reviews relevant research that tests the theory, describes the generative model of teaching and implications for instructional design, and concludes with a discussion of applications of generative learning theory in face-to-face and e-learning environments.

28.1.2 Generative Learning Foundations

Wittrock (1974a, 1974b) was the founder of generative learning theory. His beliefs about learning were influenced by research in several areas of cognitive psychology, including cognitive development, human learning, human abilities, information processing, and aptitude–treatment interactions. His work explains and prescribes teaching strategies to maximize reading comprehension. Whereas most of the original research deals specifically with reading comprehension, in theory there is much transferability to learning for understanding in general, regardless of the medium or form of the external stimuli. This chapter embraces the broader interpretation of this theory and model of learning and teaching.

In his theory, Wittrock emphasized one very significant and basic assumption: The learner is not a passive recipient of information; rather he or she is an active participant in the learning process, working to construct meaningful understanding of information found in the environment. Wittrock (1974b) states, "Although a student may not understand sentences spoken to him by his teacher, it is highly likely that a student understands sentences that he generates himself" (p. 182). It is, as Harlen and Osborne (1985) call it, "learning through the person" (p. 137). This assumption is evident in each process of Wittrock's four-part model.

Wittrock (1990, 1991, 1992) felt that the process of generation distinguished his from other theories and models of learning. He emphasized the importance of and difference between two types of learner-generated relationships: first, among the different parts of the external stimuli (information being perceived) and, second, between that information and the learner's prior knowledge. Comprehension occurs from formulating connections, rather than solely by the function of "placing" information or "transferring" information in memory. The subtle difference lies in the *creation of new* understanding of the information by the learner, rather than *changing* of the presented information. Comprehension, therefore, is not the result of a Brunerian discovery learning approach, but rather it is attributed to the process of generating relationships. A learner–self, learner–teacher, learner–learner, or learner–instruction dialogue or interaction becomes key to learning. The teacher or designer's role is "knowing how and when to facilitate the learner's construction of relations[hips]" (Wittrock, 1990, p. 352), making the learner and teacher or instruction partners in the learning process (Kourilsky, Esfandiari, & Wittrock, 1996; Mayer & Wittrock, 1996). (An analogy characterizing these important and subtle differences is presented in the next section in which generative learning is compared with other theories.)

Wittrock's three other component processes that explain learning are motivational processes, learning processes, and knowledge creation processes. Metacognitive processes also play a key role in his model, although in most cases he folds this idea into the knowledge creation process component. The concept maps in Figs. 28.1 and 28.2 are illustrative of generative learning in action. These figures represent my comprehension of the ideas presented in Wittrock's (1974a, 1974b, 1985, 1990, 1991, 1992) writings regarding the progression of generative learning from neural brain processes research to models of thinking and teaching. The lines depict personally generated relationships between different concepts and ideas presented in his writings.

As shown in Fig. 28.1, Wittrock conceptualized this model of generative learning based on a neural model of brain functioning and cognitive research on the process of knowing. From this foundation, the four components of the model are presented in shaded, rounded-off rectangles, with examples of each process presented as ovals below. For example, attribution is one example of motivational processes, and preconceptions is one example of knowledge creation processes. The process of generation is divided into two types of possible relationship creations—*coding* among different parts of the information in the text and *integration* of the information in the text with prior learning and experience. Figure 28.1 also implies a flow between the processes of the model, with motivational processes activating learning processes, which in turn affect whether the process of generation will occur. Knowledge creation processes also affect the process of generation, but in a different way: Beliefs, preconception, prior concepts, and metacognition influence the quality and type of links that learners create. Depending on the type of relationship generated, the four components converge for the purpose of learner-constructed organization, reorganization, elaboration, or reconceptualization of the information, resulting ultimately in comprehension, as shown by the hexagons. Each of these four processes is discussed in detail in later.

Figure 28.2 depicts the research by Luria (1973), as described by Wittrock (1992), on which generative learning was founded. As depicted here, Luria identified three functional units of the brain that are activated through the ascending and descending reticular activating systems and the frontal lobes of the cortex. Cognitive functioning originates in each of these units, which then activates or manages one of the processes of knowing, which then influences one of the four components of Wittrock's generative learning model—again depicted by shaded, rounded-off rectangles.

The first unit, arousal and intention, influences an individual's learning processes and motivation. External stimuli arouse attention through the ascending reticular activating system; however, without active, dynamic, and selective attending of environmental stimuli, it follows that meaning generation cannot occur regarding those stimuli. The influence of arousal on attention flows from the environment outside of the learner but interacts internally, another indication of the partnership between the learner and the instruction or teacher. Intention is activated by the descending reticular activating system, which stimulates attribution and interest. Attribution and interest influence the motivation of the learner. Attribution of effort, or the process of giving credit for success or failure to one's own effort, can influence whether or not the learner will exert the effort to be "attentive to the underlying structure of the information to be learned" (Wittrock, 1985, p. 123) and thereby become actively involved in generating understanding. If learners attribute success to themselves, it follows that motivation to exert effort will be greater than if they attribute success to external forces (Weiner, 1979). The influence of intention on motivation for meaning generation flows from within the learner.

The second functional unit is the unit for receiving, analyzing, and storing information. The coding of information is managed by the frontal lobes of the cortex. The functions of the brain in this unit influence the knowledge creation processes.

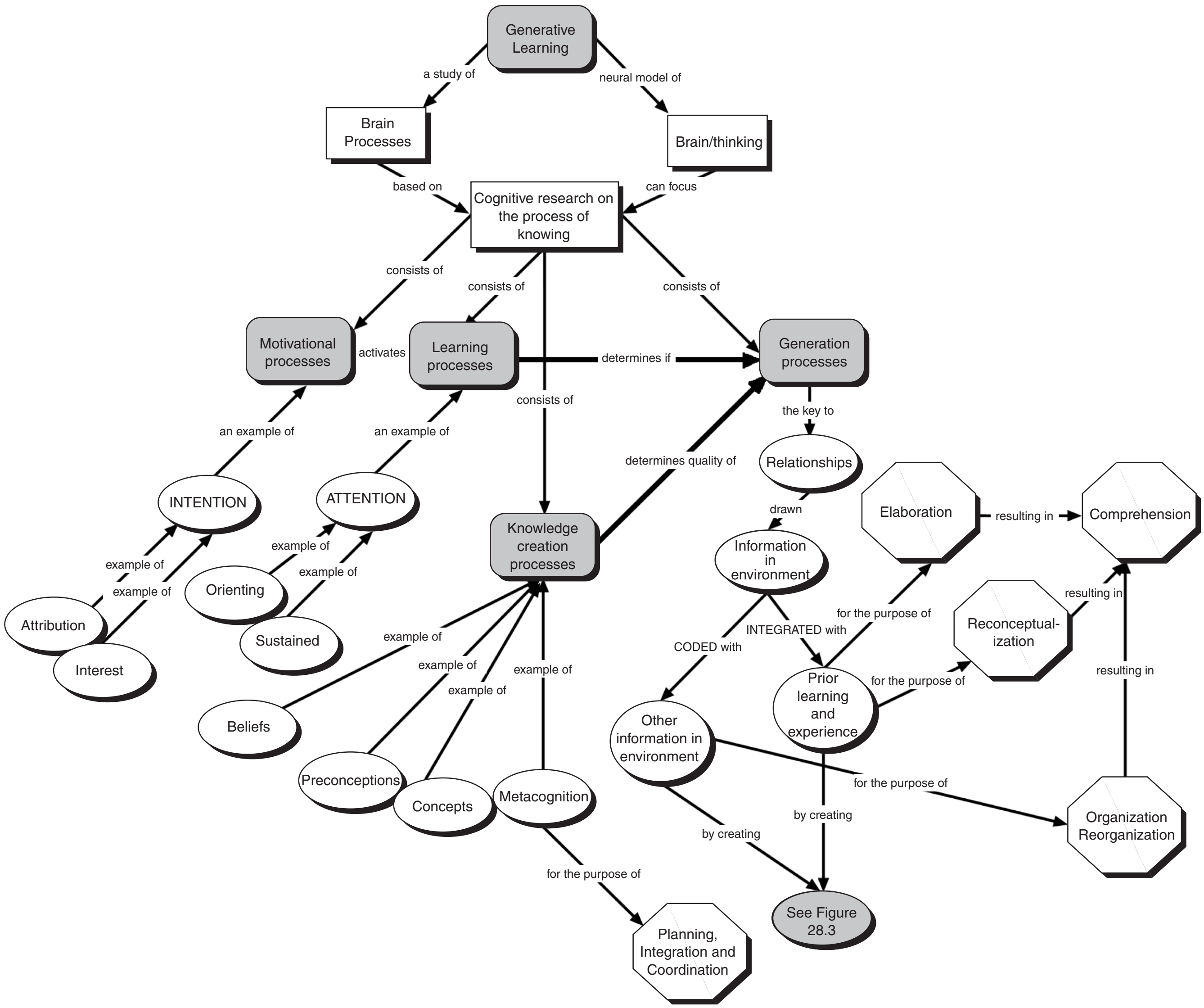

FIGURE 28.1. Generative learning concept map.

Wittrock identifies many parts to the knowledge creation processes in several of his writings. Primarily, he includes beliefs, concepts, preconceptions, metacognitions, and experiences (see Fig. 28.1). In other words, these are the components of memory. It is between these existing beliefs, concepts, preconceptions, etc., and environmental stimuli that relationships are formed, and thereby, understanding and comprehension are generated. According to Wittrock (1974a), "Cognitive theory implies that learning can be predicted and understood in terms of what the learners bring to the learning situation, how they relate the stimuli to their memories, and what they generate from their previous experiences" (p. 93).

The third functional unit is the unit for planning, organizing, and regulating cognition and behavior. This unit also operates through the frontal lobes of the cortex to coordinate learning and integrate information. These are the processes of metacognitive monitoring and generative processes—the heart and soul of generative learning theory. By generating relationships between parts of what the learners see and hear, and by integrating that information with what exists in memory, learners reorganize, elaborate, and/or reconceptualize information, not simply "stuff in more information." It is a process for which meaningful understanding and comprehension are predicted outcomes (see Fig. 28.1).

Wittrock (1990) claimed that there are two types of learning activities that can be judged as generative. Activities that generate organizational and reorganizational relationships among different components of the environment include "titles,

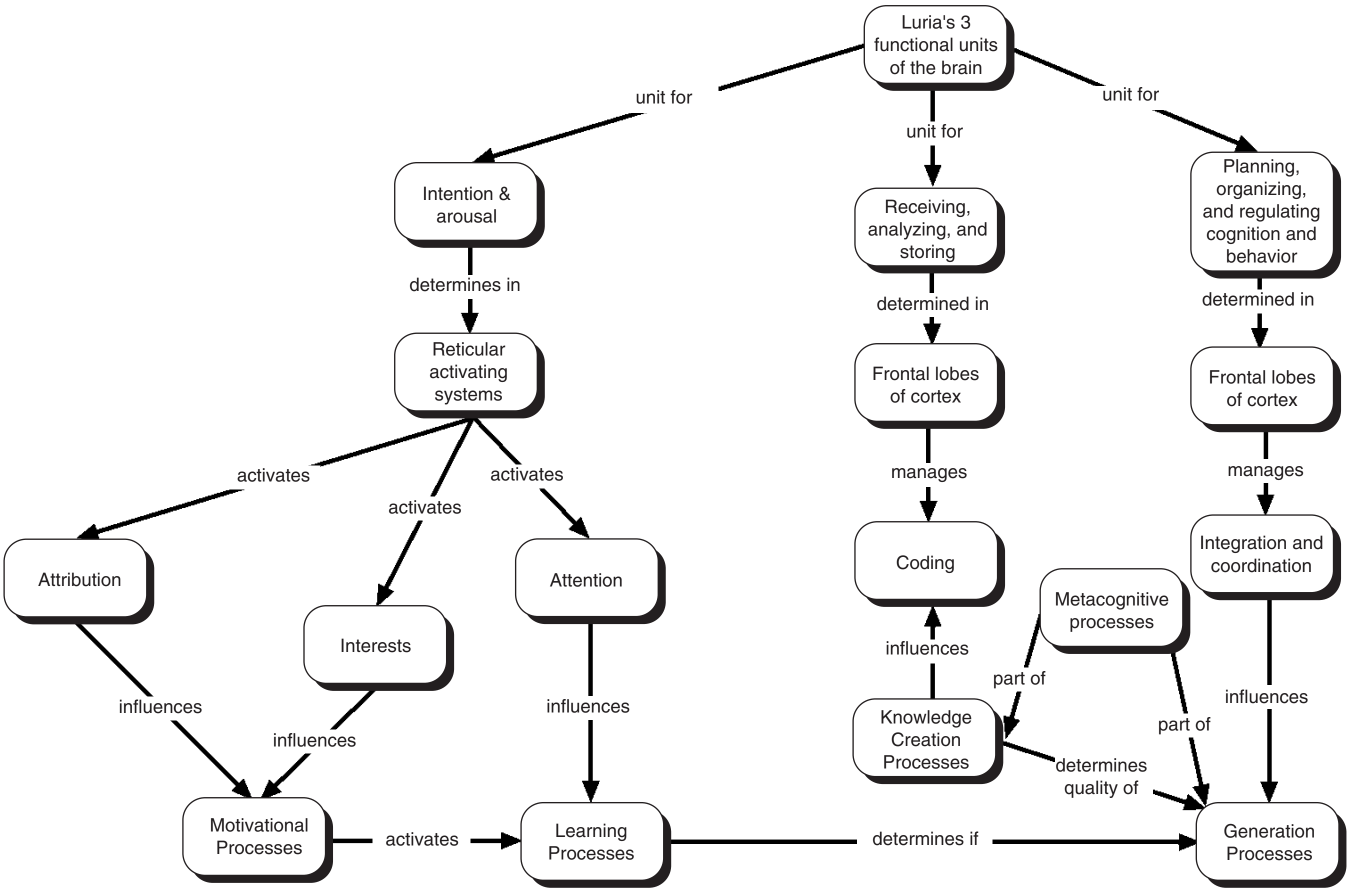

FIGURE 28.2. Neural functions concept map.

headings, questions, objectives, summaries, graphs, tables, and main ideas," whereas those that generate integrated relationships between the external stimuli and the memory components include "demonstrations, metaphors, analogies, examples, pictures, applications, interpretations, paraphrases, and inferences" (p. 354). In Fig. 28.3, these examples are shown in the ovals connected to one of the two types of relationships. From other activities proposed by DiVesta (1989), Goetz (1983), and Jonassen (1986), concept maps, diagrams, outlines, and identifying scripts within narratives seem to be appropriate additions to the organizational relationship list. Mnemonics, clarifying, and predicting seem appropriate for his second list, the integrated relationships, linking external stimuli to internal components of memory. Notetaking, diagrams, and concept maps could be appropriate for both lists, depending on which cognitive processes were used to create which type of link—organizational or integrative. That is, if learners were only relating different ideas extracted directly from a text passage, their list would be classified as organizational, whereas if they related the information to prior knowledge, it would qualify as integrative. Based on Wittrock's definition of organization and integration, Figs. 28.1 to 28.3 represent my organizational maps. Table 28.1, on the other hand, portrays generation as integration through reconceptualization and elaboration.

Only those activities that involve the actual *creation* of relationships and meaning would be classified as examples of generative learning strategies. Restructuring of environmental information by definition requires the learner to generate either organizational or integrated relationships and construct personal meaning, thereby qualifying as generative. If this activity were simply tracing, with no generation of relationships or meaning, the activity would not qualify as generative. Other controversial activities such as highlighting and underlining can be argued not to be generative, because they involve examining only single components, even though the learner may be selecting author-written main ideas. Even if learners are integrating the sentences with prior knowledge, there is no covert evidence of that integration, as the focus of the activity is a task in which they are simply selecting from among many parts. An activity must involve *meaning making* to qualify as generative. An activity in which the learner simply selects sentences that someone else has already composed cannot be considered generative. The generated main idea must relate all the ideas presented in the passage. If learners are relating the textual information to their own prior experience, knowledge, or preconception, however, it could be argued that highlighting or underlining is generative (Grabowski, 1995). As discussed later, under Applied Research, Rickards (1979) would support this notion.

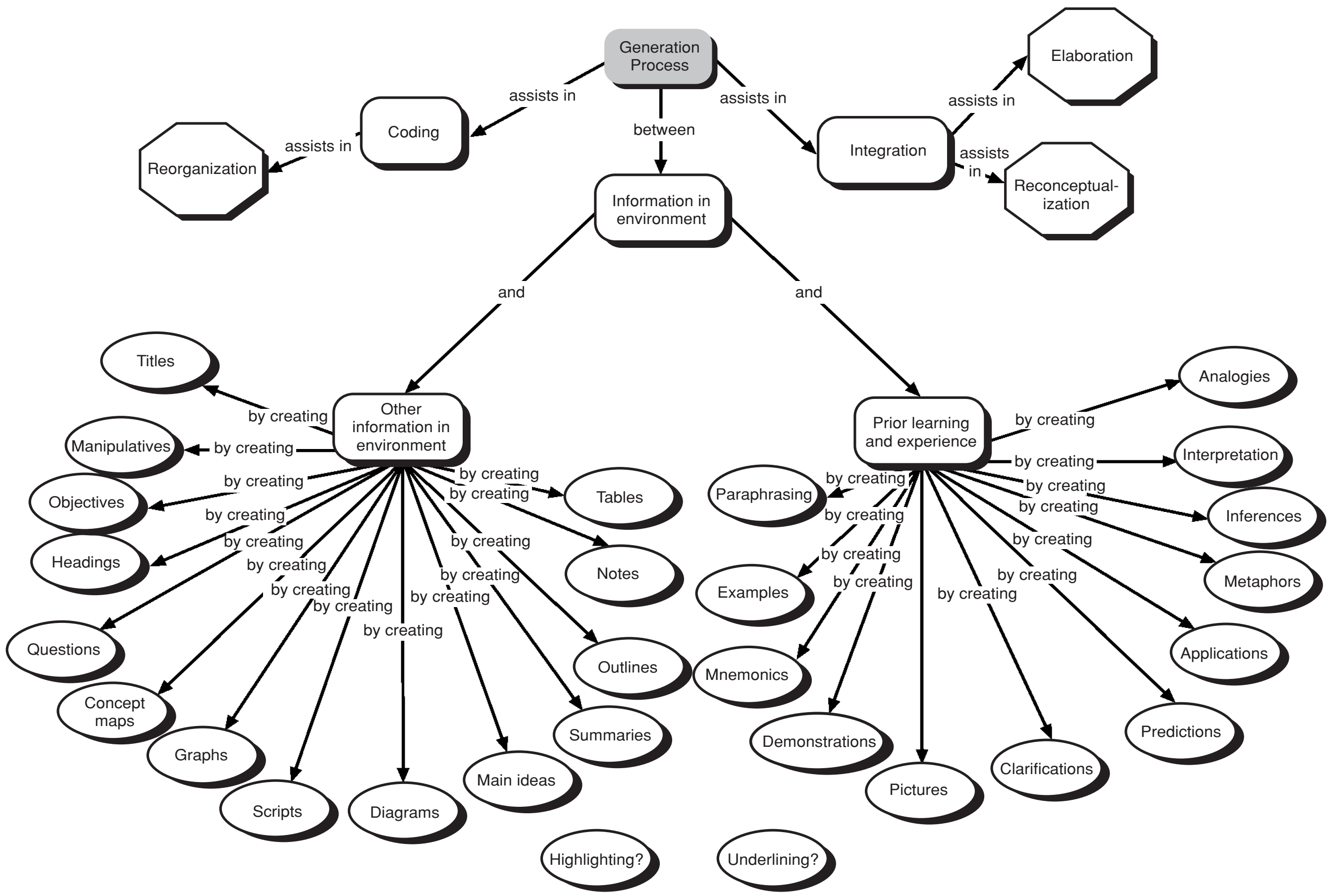

FIGURE 28.3. Generative activities concept map.

28.1.3 Relationship of Generative Learning to Other Schools of Thought

Wittrock (1991, 1992) often compares his own theory with others. These comparisons are quite useful for understanding the nuances of his teaching recommendations. In Table 28.1, generative learning theory is compared with other contemporary schools of thought: behaviorism, connectionism, schema theory, information processing, and constructivism with an integrative restructured elaboration.

These schools of thought differ in many ways, the most significant being what unit of analysis is examined and explained and how thinking and learning are defined and exemplified. These basic differences are often subtle, yet they contribute directly to the type of model that has been constructed and the implications that are drawn for instruction. The purpose of this section is not to describe each of these theories in detail (see other chapters for further description); rather, it is to discuss overall salient differences between the various models and generative learning theory and what these differences imply for instruction. The last two rows in Table 28.1 depict those differences, one directly and the other in an analogical reconceptualization.

Of all the theories, behaviorism (Skinner, 1990) presents the most extreme difference from generative learning. That difference lies in how the role of the learner is perceived and what this perception implies for learning. For generative learning, the learner is the key–the controller of whether or not information is learned. Understanding all of the neural processes that affect learning, from intention to components in memory to attribution, will aid the designer in selecting or creating appropriate activities that take these factors into account. The learner must also be actively and consciously relating ideas. For behaviorism, the learner plays no role, except as a passive recipient of information. The behavioral design of instruction must center on creating a stimulating message that reinforces by positive or negative feedback. Higher-level coding or integration is irrelevant in the prescription. An important contribution to generative learning, however, comes from extensive research on message design—this is how the external message can gain attention and be driven by designer or teacher intentionality. This contribution provides an incomplete notion of learning comprehension, thereby making it an indirect "second cousin."

Connectionisin (Wittrock, 1992) is similar to behaviorism, in that its intent is in strengthening associations. However,

TABLE 28.1. Comparison of Related Schools of Thought

Comparison	Generative Learning Theory (Wittrock, 1992)	Behaviorism (Skinner, 1990)	Connectionism (Wittrock, 1992)	Schema Theory (Rummelhart, 1981)	Information Processing (Bell-Gredler, 1986)	Constructivism (Jonassen, 1991)
A study of	Brain as controller	Neural connections	Memory associations	Knowledge representation in memory	Stages and levels of processing	Philosophy of constructed meaning
Learning defined by	Learner-generated relationships	Behavioral change	Associations	Creation of, addition to, restructuring of, or fine-tuning of schema	Process of encoding information for retrieval	Individually constructed understanding
Type of thinking	Brain as model builder by controlling the 4 processes	Automatic paired response in stimulus–response chain	Neurally induced	Schemata construction and reconstruction	Transference of external stimulus to memory so that it may be retrieved	Building understanding from experiences
Levels of thinking	Comprehension/ understanding—coding, elaboration, reorganization, reconceptualization	Unnecessary unit of analysis	Conceptual	Comprehension	Rehearsal, coding, organization, conceptualization, integration, and translation	Unspecified
Type of model	Neurally controlled learning	Stimulus–response chains	Subconceptual network model of memory	Structural (networked) knowledge representation of memory	Representation of the sequence of mental operation and form of stored knowledge	n/a
Components of theory	Four processes: motivation, learning, knowledge creation, and generation	Operant conditioning, response formation, shaping, reinforcement schedules	Networks of patterns and weights of nodes and connections	Schema, schemata, scripts, and plans	Stages—sensory receptors, short-term storage, working memory, long-term memory; levels—deep and surface processing	Source of reality, learner as builder
Implications for instruction	Activities that guide (induce) mental processes relating information	Careful construction of the physical form of messages with repeated, rewarded practice	Activities that strengthen connections through repetition	Activities that relate new to existing knowledge so that it is retrievable	Activities that activate attention, facilitate processing in working memory, and facilitate transfer into long-term memory	Creation of contextualized learning environment

Comparison with generative learning theory	n/a	Claims a very different role for the learner, as passive recipient rather than active generator	Explains learning as external neural induction instead of being neurally controlled internally; externally imposed, not necessarily personally relevant	Explains the basic knowledge unit used in generative learning theory	Explains learning as a transformation of information rather than generation	Provides a philosophical basis rather than a neurological explanation of learning
Comparative analogy: task—purchasing clothing for an outing	Approach: Active and conscious selection of items	Approach: Passive and reinforced by salesperson	Approach: Passive, externally driven	Approach: Not specified, but rather the units of clothing that can be chosen are more representative here	Approach: Active but not necessarily internally controlled; represents the process one goes through from attending to those items in the store, trying various combinations, and then taking them home to store in the closet using a variety of grouping strategies	Approach: Active—represents a philosophy that what is fashionable is constructed by individual tastes and individually defined needs rather than predefined combinations proffered in society or by salespersons
	Item purchased: The intent is creating a new fashion statement	Item purchased: Outfit created and selected by another	Item purchased: Selection of combination of items for outfit determined by those most commonly worn by peers or in magazines	Item purchased: Something to add to an existing outfit, tailoring of an old item, or creation of a new combination of items	Item purchased: Something to add to an existing outfit, tailoring of an old item, or creation of a new combination of items	Item purchased: That which has been created by the individual rather than the salesperson

the network of individual memory is important, as in generative learning theory. Connectionists, however, establish networks by strengthening associations by externally driven, repeated practice rather than creating personally drawn relationships between and among ideas. Understanding is internally created in generative learning theory, making repetitions unnecessary.

Schema theory (Rummelhart, 1981; Rummelhart & Ortony, 1977) is similar to connectionism in that it deals with patterns of data points or schemata. Basically, these data points form the knowledge units that are manipulated in generative learning theory. Because of the way knowledge is stored, instructional and learning activities must connect new to existing knowledge so that it is easily retrievable. This connection is made by adding information to a schema, restructuring it, or fine-tuning it. Although connections are made by links, those linkages are not defined or labeled, as in creating a pattern note without labeling the lines. Generative learning theory, on the other hand, is similar in concept to creating a pattern note with all the links labeled. Activities designed by schema theorists include those that remind learners of prior knowledge and relate the information to what learners already know. Who selects those connection points is less relevant than the fact that they are made.

Information processing theory (Bell-Gredler, 1986) explains the process of thinking and memory storage, in other words, the stages and levels of processing. What we take from information processing theory is an emphasis on how we think, rather than on what we think or *that* we think. Its focus is on that process of transforming external stimuli into some recallable form to be stored in memory. The emphasis of generative learning theory is on the generation of *new* conceptual understandings, not just on transforming information.

Finally, constructivism. (Jonassen, 1991) is a philosophy that underlies learning. It parallels generative theory in considering the learner to be an active processor of information; however, it is extreme in its position about the nonexistence of an objective reality. Wittrock has not addressed this approach in any of his writings, but because of its foundation, Bonn and Grabowski (2001) call generative learning theory its "practical cousin."

To explain some of these subtle differences, a comparative analogy of an individual tasked with purchasing clothing for an outing was generated showing how the approach to the task (the purchase process) and the ultimate outcome (what item would ultimately be purchased) differ between these schools of thought. The approach in generative buying would be exemplified as a buyer-controlled activity, with intention, motivation, and prior conceptions and beliefs about the outing and the people invited. These factors would drive what types and styles of clothing are perceived as needed. The generative buyer would purchase cloth and create a *new* style based on those internally stimulated factors. The salesperson, also an active participant in the purchase process, will query the buyer on how each article fits with those other influences and how the articles would go with other items the buyer had at home. Intentionality is shared, however, the buyer seeks a totally new fashion statement, rather than one already prepared.

A behavioristic example is simple: In a salesperson-driven environment, the approach is very passive, with an outfit having been preselected and the salesperson giving much praise for purchasing the item. In a connectionism scenario, the approach is also passive. Choices are driven by society-defined fashion that has been repeatedly seen (connected) in fashion magazines, on television, and on peers. A buyer purchases an outfit based on the frequency of seeing the outfit. Intention or personal conception would already have been programmed.

Following schema theory, the buyer and seller play equal roles. Though the approach is not specified by this theory, the articles of available clothing in the store and at home will play the key role. How these articles are combined is the important aspect of this theory. Accessories could be added, items rearranged, the outfit tailored to reach different desired effects. The coordination factors, however, would remain undefined. Intention, personal conceptions, or the generation of some new fashion item are irrelevant.

For information processing, both the buyer and the sales environment are essential players, meaning that the approach by the buyer is active but not necessarily internally controlled. The information processing buyer would attend to featured items that catch his or her attention, select a few, try on various combinations, and purchase a standard outfit, embellish it with accessories, or ask for it to be tailored. The key difference here is that what is purchased is transformed from a rack in a store into an appropriate outfit following established rules of fashion, rather than generating totally new fashion statements or a totally new garment from different pieces of cloth.

A constructivistic buyer would hold a philosophy that what is fashionable is constructed by individual tastes and needs rather than predefined combinations proffered by society. The approach would be very active, independent, and individually driven. The ultimate item or combination of items would make an individual statement.

In each case, the notable difference is in the role of the buyer (learner) as he or she is related to the salesperson (instructor) or store items (instruction). This is exemplified through the approach (learning process) taken to the task and the final selection of the item (learning).

28.2 APPLIED RESEARCH

Studies investigating the viability of the generative model of learning have tested the effects of simple coding strategies such as underlining, note taking, and adjunct or inserted questions; more complex coding organizational strategies such as creation of hierarchies, headings, summaries, and concept maps or manipulation of objects; elaborative integration strategies such as imaging and creation of examples, interpretations, or analogies; and, finally, metacognitive generative learning training. Table 28.2 organizes and summarizes some of the most significant work testing Wittrock's theory. The table divides the types of research into those that represent a coding generative activity and those that represent an integrative generative activity. Those that exemplify coding interrelate concepts from the instruction together to create one level of understanding through various levels and types of organizational activities. Those exemplifying integration interrelate the concepts from the instruction with prior knowledge to create a higher level of understanding by

TABLE 28.2. Summary of Selected Applied Generative Research Studies

Generative Activity	Author/Year	Dependent Variable	Content	Age Level	Results
Coding					
Underlining					
Underlining	Rickards & August (1975)	Reading comprehension	Educational psychology	College students	Increased achievement on posttest when learner underlined most relevant information.
Note taking					
Note taking	Peper & Mayer (1986)	Recall, problem solving	Auto engines	High-school & college students	Note taking increased achievement for far-transfer problem solving but not near-transfer fact retention.
Note taking	Shrager & Mayer (1989)	Recall, problem solving	How to use a camera	College students	Confirmed above findings; also significant differences for students with low prior knowledge.
Note taking, elaborated and simple review; instructor-provided and learner-generated notes	Barnett, DiVesta, & Rogozenski (1981)	Immediate and delayed recall	History	College students	Note taking produced better results than no note taking, but no significant difference between elaborated review and simple review of notes. Review of instructor-prepared notes resulted in greater learning than review of learner-generated notes. Delayed retention scores higher for questions from learner notes.
Writing summaries during note taking	Davis & Hult (1997)	Domain-specific immediate and delayed recall and free recall	Introductory psychology	College students	Summary group scored significantly higher on free recall and delayed retention test.
Précising vs. rereading underlining, or signaling	McGuire (1999)	Comprehension	Reading	ESL learners	Précising results in higher comprehension over rereading, underlining, or signaling.
Adjunct questions					
Adjunct questions: frequency, nature of, need for feedback, overt/covert responses	Anderson & Biddle (1975)	Facts, motivation, and higher-order thinking	Across content areas	Across age levels	Better learning with more frequent questions. No difference if feedback is given. Overt response needed depending on if questions were embedded.

Continues

TABLE 28.2. *continued*

Generative Activity	Author/Year	Dependent Variable	Content	Age Level	Results
Adjunct postquestions with no overt responses	Sutliff (1986)	Facts, inference	Electrical engineering	Low- and upper-ability college students	No significant differences between groups.
Adjunct questions: super-subordinate postquestions	Burton, Niles Lalik, & Reed (1986)	Recall of main ideas and details	Description of a mythical country	Undergraduates	More main ideas were recalled. General questions were more engaging than detailed ones.
Adjunct postquestions	Woods & Bernard (1987)	Recall of intentional and incidental ideas	Weather forecasting	Adults aged 60 or older	Adjunct questions aided recall of intentional ideas only.
Adjunct pictures	Brody & Legenza (1980)	Reading comprehension	History	Undergraduates	Postpictures were more beneficial than prepictures.
Organizational strategies					
Organization hierarchies	Wittrock & Carter (1975)	Free recall	Mineral tables	Undergraduates	Learner-generated hierarchies for disorganized lists significantly better than simply reproducing them. Reproducing organized hierarchies significantly better than learner-generated ones.
Organization headings, sentence meaning	Doctorow, Wittrock, & Marks (1978)	Reading comprehension	SRA literature	Elementary-school students	Learner-generated sentences combined with experimenter-provided headings produced increased comprehension, followed by generative only.
Concept vs. semantic maps	Beissner, Jonassen, & Grabowski (1993)	Drawing, identification, terminology, comprehension, and problem solving	Heart content	Undergraduates	Learner-generated concept maps better strategy for holists. Learner-generated semantic maps better for serialists for problem-solving learning only.
Concept maps	Smith & Dwyer (1995)	Drawing, identification, terminology, and comprehension	Heart content	Undergraduates	Learners using instructor-provided concept maps performed better on identification tests only. No other differences found.
Graphic organizers	Kenny (1995)	Immediate and delayed (retention) nursing assessments and interventions	Nursing elderly patients	University nursing students and faculty	Significantly poorer performance on the immediate learning and retention tests for those generative graphic organizers than those given a graphic organizer.

Concept maps—partial and total learner-generated by feedback	Taricani (2002)	Identification, terminology, comprehension tests	Heart content	Undergraduate students	Providing feedback resulted in higher terminology scores on partially generated map.
Manipulation of objects					
Physical manipulation of objects	Sayeki, Ueno, & Nagasaka (1991)	Calculating an area	Math	Elementary-school children	Posttest showed physical manipulation facilitated problem solving.
Mouse-manipulated graphics	Haag & Grabowski (1994)	Terminology, identification, comprehension, and problem solving	Heart content	Undergraduates	Leamer-manipulated graphics increased problem solving over static or computer-manipulated graphics.
Individual and group concept mapping and object manipulation; sequence of activities	Ritchie & Volkl (2000)	Immediate, intermediate, and delayed recall	Science	Sixth-grade children	No difference between concept mapping and manipulatives on immediate recall, and those who worked in teams versus those who worked individually. Significantly better performance for those who created concept maps first and then used the manipulatives on the delayed posttest. Interaction found between strategy and individual/team on immediate and delayed recall—those who created concept maps in teams performed significantly better than those who used the manipulatives in teams. The opposite effect was found for intermediate recall.
			Integration		
Imaging					
Imaging	Anderson & Kulhavey (1972)	Prose learning	Fictitious description of a tribe of people	High-school seniors	Significant differences in favor of those who actually used an imaging strategy.
Imaging–experimenter provided/ learner generated	Bull & Wittrock (1973)	Recall of verbal definitions	Definitions of nouns	Elementary-school children	Recall was significantly higher for imaging than verbal/copying strategy.
Verbal and image elaborations: *sequence*	Kourilsky & Wittrock (1987)	Economic understanding	Economics	High-school students	Verbal-to-image elaborations significantly better than image to verbal or either used singularly.

Continues

TABLE 28.2. *continued*

Generative Activity	Author/Year	Dependent Variable	Content	Age Level	Results
Verbal only, image only, and combined elaborations	Laney (1990)	Reasoning in decision making	Economics	Third-grade children	Verbal-only and verbal-to-image integrated strategies facilitated reasoning better than imagery only.
Elaborations					
Elaborations elaborated sentences	Stein & Bransford (1979)	Retention	Language arts	Undergraduates	Performance facilitated only when elaborations clarified precise objectives prompting encouraged subjects to ask more relevant questions.
Elaboration examples	DiVesta & Peverley (1984)	Concept attainment near and far transfer	Fictitious concepts	Undergraduates	Students who generated their own examples did significantly better on far-transfer tasks than those given instructor-provided examples.
Elaboration interpretation	Johnsey, Morrison, & Ross (1992)	Recall, recognition, application, type of elaborations	Professional development	Adults	Results favored the use of embedded vs. detached elaboration strategies. Elaborations better than no elaborations. No difference between learner-generated and experimenter-provided.
Combination of Coding and Integration					
Images, verbalization of the image and summaries, structural adjunct questions,	Carnine & Kinder (1985)	Reading comprehension	Social studies and science	Low-performing elementary-school children	Comprehension increased significantly but not more than when inserted questions on passage structure were used.
Summaries, and analogies	Wittrock & Alesandrini (1990)	Text	Marine life	Undergraduates	Summaries facilitated reading comprehension better than analogies, and both did better than reading alone.
Summaries and analogies: alone and in pairs	Hooper, Sales, & Rysavy (1994)	Achievement, efficiency, and generations	Marine life	Undergraduates	Those who generated summaries performed better than those who generated analogies. Students working alone did better than those working in pairs.
Combination of generative strategies—images summary sentences, and analogies/metaphors	Linden & Wittrock (1981)	Factual retention and comprehension	Reading	Elementary-school children	All generations increased and correlated with comprehension. More generations were produced when images were produced before verbal elaborations. *No* difference by generation sequence. Results were mixed for factual recall.

Self-questioning, summarizing, and note taking	King (1992)	Immediate and delayed recall	Generic lecture	Underprepared undergraduate students	Immediate: Summarizers performed better than self-questioners, who performed better than note takers. Delayed: Self-questioners performed better than summarizers, who performed better than note takers.
Summaries, analogies, and question answering in different sequences	BouJaoude & Tamin (1998)	Comprehension and preference	Science	Seventh-grade students	No differences for strategy or sequence. Preferred summaries the most, and questions because they were easy, analogies for fun, and summaries for their helpfulness.
Strategy orientation (underlining, headings, and analogies) by guided vs. active activity	McKeague & DiVesta (1996)	Memory, organization, and application	Radar	Undergraduates	No effect by strategy.
					Students performed better in the guided activities than the active learner groups.
		Metacognitive Strategies			
Generative learning processes training	Kourilsky & Wittrock (1992)	Comprehension, confidence, misunderstanding	Economics	High-school seniors	Generative learning procedures significantly increased confidence and decreased level of misunderstanding.
Generative teaching training	Kourilsky (1993)	Comprehension, misunderstanding	Economics	Professional teachers	Pre- to posttest gains on both exams were significant when misconceptions were clarified and learning covered again.
Instruction on summary writing versus reflection training	Friend (1999)	Judging importance of content/construction of a thesis statement	Reading comprehension	Unskilled undergraduate writers	Instruction on how to write effective summaries was more effective.

reconceptualization and elaboration. A discussion and summary of the results from each of these areas are provided. This discussion begins with the most controversial—underlining—so that it neither gets lost among the other significant, noncontroversial studies nor is given the same importance as many of the other studies reported here.

28.2.1 Simple Coding

28.2.1.1 Underlining. As discussed previously, an argument can be made for activating generative processes by having the learner consciously and interactively relate information in the passage with prior beliefs and conceptions. This is, in essence, what Rickards and August (1975) did in their study. They investigated subject-generated versus experimenter-provided underlining strategies under six treatment conditions. Their results indicated that when college students had an opportunity to underline text that they considered most relevant, they performed better on the posttests on both objective-specific and incidental learning (total recall). In fact, a very interesting result was that in the learner-generated condition, in which the subjects were asked to underline the least important items, they did poorest of all. Rickards (1979) explained that because learners were asked to underline those sentences that were more relevant to them, a mental interaction between sentences and between what they read and their own preconceptions had to occur, thereby establishing plausible evidence that learner-constructed generative learning occurred.

28.2.1.2 Note Taking. Note taking is also considered an organizational coding strategy by some. Others would argue that no generation of understanding occurs when a learner simply copies sentences from a page. As with the Rickards' argument, however, a learner that rewords sentences to combine ideas from the passage or relate them to prior knowledge is engaging in generative activity. This is an important distinction for teachers as they teach learners how to take notes and provide feedback in the process. To illustrate, five studies have been selected that include high-school and college students in vocational education, liberal arts, and English as a second language (ESL).

Peper and Mayer (1986) found from two experiments, one with high-school and one with college-level students, that note takers performed better than non-note takers on far-transfer tasks of problem solving but worse on near-transfer tasks of fact retention and verbatim recognition (p. 34). Shrager and Mayer's (1989) study of college students instructed to take notes or not to take notes of a videotaped lesson confirmed these findings and found that the effect on recall and transfer was highest for learners with low prior knowledge. Peper and Mayer also tested the effects of other generative strategies, such as taking summary notes and answering conceptual questions during breaks in lectures, and produced similar results. This study points out the importance of examining the effects of generative strategies on the type of learning that results.

Davis and Hult (1997) added another dimension to note taking—that of writing summaries as specified periods during note taking in introductory psychology classes. Their results support the findings of Barnett, DiVesta, and Rogozenski (1981) that writing summaries during pauses in the lecture note-taking activity significantly improved free recall and delayed retention. The summaries added an important generative dimension to the note-taking activity. McGuire (1999) compared précis writing (summaring) to rereading, underlining, or signaling for ESL learning. Her contribution to this body of work is the positive effect of summarizing for ESL.

Note taking in two studies by Barnett et al. (1981) was hypothesized to aid college students' processing of information. Note taking produced better results in learning from text than no note taking, but elaboration of the notes during a review period, a generative activity, produced similar results in terms of amount of learning as those who simply reviewed their notes. An interesting dimension to this study was the inclusion of instructor-prepared notes vs. learner-generated notes. For immediate recall tests during which learners had an opportunity to review or elaborate on instructor-prepared notes, they performed better than the learner-generated notes group. The second study tested whether the effects were the same for different types of questions: those common to the group, those from their own notes, those from others' notes, and those from others' elaborations. Scores for the delayed test using questions written from student's own notes were dramatically higher than for the other groups. This provides a strong case for note taking causing generative effects. In other words, these results showed that learners remembered what they originally perceived and encoded versus what others had intended them to remember.

To summarize these studies, note taking has shown positive effects, but there were mixed findings compared with type of learning. Note taking may be a highly generative activity; however, quality of notes, type of elaborations, and opportunity for review can affect what, how much, and for how long information is learned. Another important implication is that for a learning partnership to occur between the instruction or instructor and the learner, an interaction is required—a dialogue between the learner and the instructor about the match between instructor intention and learner generation.

28.2.1.3 Adjunct or Inserted Questions. Wittrock (1990) classified adjunct questions as a generative activity. They function as a scaffold for coding and organizing external stimuli. Whereas learners can generate questions, Wittrock believes that providing questions intentionally induces generative thinking by stimulating attention and intention of the learner to relate ideas from a passage together, thereby creating personally meaningful understanding.

Over the past 35 years, the effects of inserted or adjunct questions have been studied extensively across content areas and age levels. Two important reviews of this research have summarized those findings. Anderson and Biddle (1975) and Rickards (1979) have concluded that inserted postquestions have been shown to increase recall of incidental learning (where criterion questions are unrelated to the inserted questions) as well as increasing recall on intentional learning (i.e., where criterion questions are the same as the inserted questions). Prequestions have been shown to increase intentional learning only.

According to Anderson and Biddle (1975), adjunct questions have been examined in terms of frequency, need for feedback, nature of the question, need for overt responding, and motivation. They summarized the findings as follows: The more frequent the questions, the better; feedback increased learning, but so did inserted questions without feedback; whereas most of the research focused on fact-level questions, there was also a positive effect for higher-level questions; free recall was generally better than multiple choice; a need for overt responding was dependent on how the questions were embedded; and the questions did motivate learners in some cases. They also found that these effects held across age level, content, length of text, and medium used.

Sutliff (1986) investigated the effect of inserted questions on reducing passivity in a self-instructional slide–tape presentation as evidenced by increased learning of facts (direct learning) and inference (indirect learning). His findings were opposite those of Anderson and Biddle in that there were no significant differences between groups. He interpreted the nonsignificance to be a result of not requiring overt responses to the questions, again contrary to previous research. Because of this "veto power over learning," described by Rothkopf (1976, p. 94), results such as this need to be examined further to determine just where overt manifestations may be necessary to ensure that processing occurs.

Burton, Niles, Lalik, and Reed (1986) investigated the effect of superordinate and subordinate questions on the amount of mental effort (level of cognitive capacity engagement) by using a secondary task probe technique and a passage about a mythical country. They found that superordinate questions have a greater learning effect and that the effect carries over into subsequent text. The overall results indicated that more main ideas were recalled than details. The explanation of the effect was that superordinate information is pulled into short-term memory more frequently, so it gets more practice. In other words, they found that general questions are more mentally engaging than detailed ones.

Woods and Bernard (1987) also found effects contrary to those of the reviews by Anderson and Biddle and by Rickards. They investigated the effects of adjunct conceptual postquestions for encouraging greater depth of processing of verbal information of adults 60 and older. From results on intentional and incidental free-recall tests, they found that adjunct questions helped older learners process only intentional text at a greater depth.

In an interesting twist on the research question, Brody and Legenza (1980) studied the effect on learning of inserted pictures as opposed to inserted questions and hypothesized that the effect would be the same as the results on adjunct questions. Their findings supported their hypothesis that postpictures were more beneficial to reading comprehension than prepictures.

To summarize the numerous studies: Postquestions and postpictures have been shown to be most effective for increasing both intentional and incidental learning, superordinate questions have been more effective than subordinate detail questions, and overt responses have been more effective than allowing covert responses.

28.2.2 Complex Coding

28.2.2.1 Organizational Strategies. This topic deals with a variety of coding and organizational activities including creating hierarchies, headings, and sentence meanings and mapping techniques across all age levels, from elementary-school children to professionals, in a variety of topics, from science to language arts. These organizational tasks require learners to relate ideas from a passage together by using a variety of symbolic representations. Each addresses at least one of three key questions regarding the generative model of learning: the effect of learner-generated learning vs. the effect of learner-reproductive learning; the effect of learner-generated vs. instructor-provided constructions of meaning, including organization as a variable; or the general effects of generated elaborations.

Wittrock and Carter (1975) studied free-recall responses of undergraduates in generative vs. reproductive treatments using hierarchies with varying degrees of order. The generative group was directed to organize the hierarchies, whereas the reproductive group was directed to simply copy them. The results showed better performance for the generative treatment groups than for the reproductive groups for the disorganized and randomly organized hierarchies. However, the organized reproductive group performed better than the unrelated generative group. This means that organization within the stimuli can compensate somewhat for a lack of learner-generated strategies, but providing organization in the instruction *and* opportunities for generative activity will be the best.

In two experiments with elementary-school children, Doctorow, Wittrock, and Marks (1978) studied the effect of learner-generated vs. experimenter-provided paragraph headings and sentence meanings on comprehension. Again, the combination of text organized through the use of headings plus learner-generated sentences about the paragraphs produced dramatic gains in comprehension and recall. Generative instructions without experimenter-provided headings followed as the next most effective, and paragraph headings alone were more effective than the control group. This strategy also increased comprehension more for high-ability students than for low-ability students, perhaps because high-ability students have better organizational cognitive abilities to make sense out of disorganized information.

Beissner, Jonassen, and Grabowski (1993) tested the effects of two organizational strategies against learner differences at four levels of learning. Their findings showed an interaction between learner-generated concept vs. semantic maps and serialist or holist learners on the problem-solving questions only, with serialists performing better with semantic maps and holists performing better with concept maps. Although this study did not compare their results with instructor-provided maps, it does contribute evidence to the importance of individual cognitive strengths and patterns of thinking when selecting organizational learning activities.

Also studying the effects of concept maps, Smith and Dwyer (1995) found a significant difference only on lower-level terminology tasks in favor of instructor-provided maps. This result is consistent with that found by Wittrock and Carter (1975). For lower-level tasks, organization helps, especially when a learner is tested with questions that show similarity to the organization that an instructor may have possessed when creating the test.

Two other studies (Kenny, 1995; Taricani, 2002) found no effects of learner generated graphic organizers or concept maps. In the Kenny (1995) study, it appeared that the computer-based interactive instruction lacked an organization that the instructor provided graphic organizer provided. Subsequent subject interviews supported this notion. In the Taricani (2002) study, feedback was also tested against generativity, testing the notion that learner generation can create misconceptions that are corrected before testing. Her results support this hypothesis for the terminology test in the partially generated treatment group.

To summarize the findings of these studies, the results are mixed when comparing learner generativity. Some studies show that learner-generated activities are more effective in improving achievement than instruction-provided organizational schemes and that performance is increased even more when the text is organized. However, other studies found that instructor-provided activites produced better results when the instruction is disorganized and when feedback is provided. Finally, the selection of activities should be tempered by cognitive ability. Given these results, it is clear that more research is needed to understand these results more fully, especially in the area of concept map generation.

28.2.2.2 Manipulation of Objects. The next organizational activity is manipulating objects. Although this activity extends beyond the printed page as designated by Wittrock's work, it qualifies as a generative activity because a relationship is being drawn and extended between parts of the environment.

Sayeki, Ueno, and Nagasaka (1991), in a very interesting study, investigated the effects of transforming mediation objects in the learning of mathematical principles. Their results supported the hypothesis that manipulatives increase comprehension. Although they do not specifically call this a generative activity, the act of creating understanding by generating both mental and physical relationships from different shapes of a manipulable rectangle manifests the same required attributes defined by Wittrock. Their results from mathematics should be tested for conceptual learning and problem solving in other content areas.

Haag and Grabowski (1994) extended this work to computer-manipulated graphics. Most applications of moving or manipulated graphics are done through generated animation. In this study, they found that learners who manipulated the graphics on the screen using a preorganized framework increased problem solving over those using no organizational framework or having the computer create the graphic statically. These results are consistent with those of other organizational strategies reported in the previous section.

Ritchie and Volkl (2002) found no difference between concept mapping and object manipulation—perhaps due to the generative nature of both activities. However, they did find a difference between these two strategies when sequence was added to the mix. Those students who *first* created concept maps and then used the manipulatives performed better on a delayed posttest. They also tested the team vs. individual generation effect and found an interaction between strategy and individual or team interaction.

These studies lend support to the use of manipulatives for generating understanding for children and undergraduates in math and science. Compared with concept mapping, however, sequence played a part in its effectiveness.

28.2.3 Integration Strategies

The next series of studies examines the effects of activities that require a student to relate information to prior knowledge. In these activities, learners are integrating information through imaging, elaborations, and analogies.

28.2.3.1 Imaging. The effects of imaging have been investigated extensively in four of those studies summarized here. They include fictitious descriptions, language arts, and economics topics studied by elementary- or high-school students.

Anderson and Kulhavey (1972) studied prose learning of high-school seniors to determine the effect of imaging. In this study, half of the subjects were told to image, and the other half were not. Results indicated no difference in prose learning between the groups. On further probing, the researchers discovered that not all of the students in the imaging group actually created images (only 50% did), and many in the control group created images (about one-third)! Comparing subjects from both groups who actually used imaging with those who did not showed significant differences in favor of the imaging strategy. These results illustrate the fact that mental activity cannot be strictly controlled by instruction and, again, raises the issue that requiring an overt response may be more effective in encouraging the desired result than just simply providing direction to image, as Sutliff (1986) found with adjunct questions.

Bull and Wittrock (1973) compared the effect of experimenter-provided vs. learner-generated imagery with elementary-school children. Groups were directed to draw, trace, or copy definitions. As predicted, results showed that the group that generated images performed significantly better than those who copied definitions; however, there was no significant difference between the imagery provided (tracing) and the copied definitions groups.

Kourilsky and Wittrock (1987) investigated what effect the sequence of the use of verbal or imaging generative activities would have on economic understanding by high-school students. They found that using verbal elaborations first, followed by imaging, significantly increased economic understanding. They also found significantly greater gains using both generative activities (verbal and imaged) than using just verbal elaboration only.

Laney (1990) found a slightly different result. Examining economic reasoning of third-graders, he found that the verbal-only and integrated strategies were more effective than the imaging-only strategy. Whereas using both symbol systems increased learning in both studies, the verbal-only elaboration was more effective than both the imaging-only strategy and the use of dual-symbol systems. He felt that his results were consistent with Wittrock's notion that the effective use of imaging is developmental. Laney's third-grade subjects had not yet developed this ability and were more familiar with verbal instruction. These are important results given the confusion that could result from the use of a generative imaging strategy too early in a learner's developmental cycle.

In summary, these studies have shown that overt imaging is more effective than covert; learner-generated imaging is more effective than instruction-provided imaging; and visual images may be more effective than verbal ones, only in cases in which students have progressed developmentally to the point where they can understand images. The sequence of generative activity also played a part in the results found for imaging.

28.2.3.2 Elaborations. Stein and Bransford (1979) conducted two studies to determine the effects of learner-generated or experimenter-provided sentence elaborations by type. They hypothesized that congruence of the elaboration with the topic would be the determining variable and, in fact, did find differences in two experiments with undergraduates. In those cases in which elaborations were incongruent, students did worse than those in the treatments with no elaborations at all. Two important findings indicated that "elaborations facilitated performance only when they clarify the precise significance of target concepts . . . and that prompting subjects to ask relevant questions facilitated both the precision of elaboration and subsequent retention" (p. 769).

DiVesta and Peverley (1984), in a very complex study, tested learner-organized vs. preorganized examples on near and far transfer in a concept attainment lesson. Additional variables included variability of examples and sequence. Their results on the active vs. passive element of their study indicated that students who generated their own examples did significantly better on both transfer tests than the preorganized group.

Johnsey, Morrison, and Ross (1992) investigated the effects of embedded vs. detached and learner-generated vs. experimenter-provided elaboration on recall, recognition, and application learning. The type of elaborations tested in this study in the area of adult professional development included two types of statements relating the content of the lesson to their job and stating implications of the information presented to their job environment. When these elaborations were embedded in the CAI training, significant gains were found; however, there were no differences between the learner-generated and the experimenter-provided elaborations. Teaching students how to generate elaborations at the time they will need them appears to be consistent with "just-in-time" training, especially when the technique may be new or more mentally difficult to implement.

To summarize these findings, elaborations that are congruent with intentional targets, student-generated question elaborations, student-generated examples, and student-generated relevant questions seem to improve retention and transfer, but not always more than instructor-provided elaborations.

28.2.4 Combination and Comparison of Coding and Integration Strategies

Carnine and Kinder (1985) expanded on the Anderson and Kulhavey (1972) study on imaging. In their investigation, elementary-school subjects were asked to form an image and verbalize it and were then given corrective feedback. They were also asked to create a summary at the end. This strategy was compared to a "schema-based strategy" in which learners were asked structurally related questions about the passage composition. They found significant gains in reading comprehension from pre- to posttests for both narrative and expository text for both treatments. One cannot be sure whether the positive results were due to the additional instructional effects or the feedback. Nevertheless, the question of the need for feedback on learner-generated activities is an important one because significant differences favoring adjunct questioning over the imaging strategy were observed for learning of expository materials.

Linden and Wittrock (1981) conducted a study with elementary-school children that found that students who were asked to generate text-related summaries, analogies, metaphors, and pictures had better comprehension than those who were not. When instructed to generate images before verbal explanations, students produced more generations.

Wittrock and Alesandrini (1990) also investigated the effects of learner-generated summaries and analogies by analytic and holist undergraduates. The results followed the predicted rank ordering, with the most positive effects found for generating summaries, followed by generating analogies, both of which were significantly better than the control group containing no generative activities. They also found that individual differences in analytic and holist ability correlated with learning differently in the three treatments: analytic ability with learning in the generate analogies group, holist ability with the text-only control group, and both analytic and holist abilities in the generate summaries treatment.

Hooper, Sales, and Rysavy (1994) tested individual and paired undergraduates on achievement efficiency and generations when given summaries and analogies. They found that those who generated summaries performed better than those who generated analogies. Contrary to expected predictions, students working alone did better than those working in pairs.

BouJaoude and Tamin (1998) and McKeague and DiVesta (1996) also studied the effects of summaries and analogies. BouJaode and Tamin (1998) added question answering to the mix. They found no differences for stategy or sequence of the strategy. What was important in their study was the finding about preferences. Overall, their seventh-grade students preferred summaries the most often, but reasons stated for preferences noted ease for the questions, fun for analogies, and helpfulness for summaries. McKeague and DiVesta (1996) also found no strategy difference among underlining, headings, and analogies, but they did find that those who were guided performed better than those in the active learner group.

Finally, King (1992) examined the effect of self-questioning, summarizing, and note taking on immediate and delayed recall of underprepared college students. On the immediate recall, summarizers performed better than self-questioners, who were better than note takers, indicating a progressive generative effect. Self-questioners performed best on the delayed tests, indicating that deeper processing may occur in more generative tasks like self-questioning.

To summarize, earlier research suggests that when using a combination of strategies, the difficulty of the task must be taken into consideration, and, where possible, the effects of cognitive strengths factored in. Imaging is a more difficult task than adjunct questions, and analogies are more difficult than summaries. Also, self-questioning may be more difficult than writing summaries. If learners are not developmentally ready for such a task, it may cause more frustration than positive effects. Sequencing the tasks may also contribute to preparing the learner for more complex cognitive processing. However, more recent research found no results for strategy for undergraduates or middle-school children. More research is needed to tease out the variables causing this effect in the later, more complex studies.

28.2.5 Metacognitive Processes

Kourilsky and Wittrock (1992), in a very powerful study, investigated the effect of teaching the overall generative model of teaching, including its four processes and activities, to senior high-school students. The seniors were taught economics in cooperative learning groups. Those students who were taught this way of thinking were found to be more confident, had significantly fewer misconceptions, and had greater comprehension than those without this training. A fascinating result consistent with the Hooper et al. (1994) study was that using cooperative learning groups alone did not produce as great an effect.

Kourilsky (1993) taught professional teachers generative teaching strategies and economic misconceptions. She found that pre- to posttest gains on exams of comprehension and misunderstanding were significant when misconceptions were clarified. This result also provides support for the notion of partnership among the learner, instructor, and instruction. Without a dialogue, misconceptions can be generated and sustained.

Finally, Friend (2001) tested the effect of providing training on judging the importance of content and construction of a thesis statement over providing reflective thinking training. Their results showed a positive effect of the training on noting argument repetition and generalization. These findings are important in that they indicate that cognitive skill may play a large role in generative activity selection.

These studies lend support for teaching generative thinking to students, making them independent learners. One caution is noted, however. In their generation or understanding, students may actually create misconceptions about the content.

28.2.6 Summary

A variety of studies reporting on results of generative strategies has been summarized here. This section was not intended to be exhaustive; rather the studies were selected as representative of the kind of research that has been conducted across content areas, learning types, and age levels. However, all articles that could be found that specify generative learning as the theory being tested were included. In general, results have shown increased gains in learning when the learner is an active partner versus a passive participant in the learning process and when instruction includes activities that relate new information together and new information to prior knowledge. These studies on generative learning have shown that, in most cases, active learner involvement produced increased learning, i.e., learner-generated activities have resulted in significant gains in learning, although issues of misconception, provision of feedback, and developmental appropriateness require investigation regarding differences in effect.

28.3 THE GENERATIVE MODEL OF TEACHING AND IMPLICATIONS FOR INSTRUCTIONAL DESIGN

Instructional designers engage in the systematic process of analyzing, designing, developing, evaluating, and implementing instruction. Although "effective instruction [in the generative model of learning] causes the learner to generate a relationship between new information and previous experience" (Wittrock, 1974a, p. 182), it is brought about by considering the four processes defined by generative learning theory. Ignoring any one of these processes could result in the learner's taking a "passive," mentally disengaged approach to learning. Generative learning theory is most applicable to the design and development phases, although there are implications for analysis and evaluation. Four of the five phases of the instructional design process, therefore, can be matched to the four generative processes that work in tandem to create learning: motivation, learning, knowledge creation, and generation. See Table 28.3.

The goal of the analysis phase is to understand the task and the learner. The goal of the design phase is to select appropriate strategies and tactics that match needs defined in the analysis phase. The goal of the development phase is to create effective instruction through effective message design that is organized and causes some level of mental activity on the part of the learner (Grabowski, 1991). The goal of the evaluation phase is to determine if the instruction that was created was effective. Specific implications of each of the four processes are noted in Table 28.3. These were selected from the many practical guidelines and suggestions offered by the generative model of teaching and generative learning theory that extend beyond simply suggesting those learning activities that induce relationship building. Creating a teaching model to provide practical prescriptions for teachers was Wittrock's original intent in pursing this area of research. As such, he provides some important recommendations that affect the four processes of his model.

28.3.1 Motivation Processes

Wittrock (1991) specifies interest and attribution as the two essential and linked components of motivation processes (see Figs. 28.1 and 28.2) that are activated by arousal and intention through the descending reticular activation system. Research from other areas suggests that attribution of effort, or the process of giving credit for success or failure to one's own effort,

TABLE 28.3. Instructional Development Process Matched with Generative Learning Theory

Instructional Development Process	Processes of Generative Learning Theory	Implications
Analysis	Motivation	Understanding learner's concept of self as learner
	Learning	Understanding current interests
	Knowledge creation	Understanding learner's beliefs, concepts, metacognitive ability, and prior experiences
	Generation	Understanding cognitive processes required of the task
Design	Motivation and knowledge creation	Strategies selected to help learners attribute learning to their own effort; create satisfaction; control for one's own learning.
	Knowledge creation	Select activities that match cognitive strengths *or* include instruction on how to engage in the generative activity.
	Generation	Select strategies that engage learners in the process of relating information or relating information to themselves.
Development	Learning	Use effective message design strategies to gain and maintain attention.
Evaluation	Generation	Evaluate whether the learner engaged in the generative activity.
		Evaluate the products generated by the learner to note misconceptions.

can influence whether or not the learner will exert the effort to learn actively. If learners attribute success to themselves, it follows that motivation to exert effort will be greater than if they attribute success to external forces (Weiner, 1979). The influence of intention on motivation for meaning generation flows from within the learner. Wittrock (1990, 1991) suggests that addressing this component means providing opportunities for the learner to "take control and responsibility for being active in learning" (p. 175). Teaching and design strategies that deal with attribution should result in enduring interest, persistence, and motivation. He suggests those activities or teaching strategies that

- attribute learning to learners' own effort,
- improve learners' self-concept,
- create satisfaction from the process of learning,
- modify learners' perception of themselves as learners,
- create control and increase responsibility and accountability for learning, and
- use rewards and praise that can be directly attributable to learners' own effort.

28.3.2 Learning Processes

Arousal and intention in the brain also influence an individual's learning processes. External stimuli arouse attention through the ascending reticular activating system. Without active, dynamic, and selective attending of an environmental stimulus, it follows that meaning generation cannot occur regarding that environmental stimulus. The influence of arousal on attention flows from the environment outside of the learner but interacts internally. The learning process that is key to this model is attention. Without attention, learning cannot occur. Teaching and design activities that can assist in gaining and maintaining attention include those that

- provide attention training by self-control, planning, and organizing;
- provide behavioral objectives and adjunct questions;
- provide interpretation of the importance of the topic selected;
- use problems, mysteries, inconsistencies, suspense, and enigmas; and
- direct students' voluntary attention to meaning.

28.3.3 Knowledge Creation Processes

Knowledge creation processes are those components of memory—including preconceptions, beliefs, concepts, metacognitions, and experiences—activated through the frontal lobes of the cortex, which manage the receipt, coding, and storage of information. It is between these existing beliefs, concepts, preconceptions, etc., and environmental stimuli that relationships are formed, and, thereby, understanding and comprehension are generated (Wittrock, 1990, 1991). Much of Wittrock's writing and research with colleagues addresses the notion of preconceptions as they influence learning misconceptions (Kourilsky & Wittrock, 1987; Benson, Wittrock, & Bauer, 1993). Some would assert that creating dissonance in the learner is one way to "unteach" misconceptions. Wittrock (1990) would argue that those dissonant situations must be carefully selected experiences that are real to the learner so that the learner cannot easily dismiss the situation as untrue. He also suggests teaching scientific conceptions early—before preconceptions are formed.

TABLE 28.4. Match of Generative Activity with Level of Processing

Level of Cognitive Processing	Recommended Generative Activity
Coding	Creating titles and labels
Organization	Outlining
	Summarizing
	Diagramming
Conceptualization	Paraphrasing
	Explaining/clarifying
	Creating concept maps
	Identifying important information
Integration	Creating relevant examples
	Relating to prior knowledge
	Creating analogies
	Creating metaphors
	Synthesizing
Translation	Evaluating
	Questioning
	Analyzing
	Predicting
	Inferring

Preconceptions about learning and the learning process also function as a primary influence on learning. It may be necessary to change one's beliefs about learning and the learner's role to understand the value of participating in generative activities.

Other strategy recommendations offered by Wittrock (1990,1991) include the following.

- relating instruction to background knowledge and interest;
- teaching metacognitive processes to monitor learning actively;
- demonstrating tangible results from active learning.

28.3.4 Generation Processes

"The art of generative teaching is knowing how and when to facilitate the learner's construction of relations among the parts of the text and their knowledge" (Wittrock, 1990, p. 353). Stimulated by the frontal lobes of the cortex, learners generate relationships between parts of what they see and hear. By integrating that information with what exists in memory, learners reorganize, elaborate, and/or reconceptualize information.

Two types of activities can be judged as generative. Those that generate organizational relationships among different components of the environment include "titles, headings, questions, objectives, summaries, graphs tables, and main ideas." Those that generate integrated relationships between the external stimuli and the memory components include "demonstrations, metaphors, analogies, examples, pictures, applications, interpretations, paraphrases, inferences" (Wittrock, 1990, p. 354).

Both of these types of activities can be used in an instructor-provided or a learner-generated format. In other words, the teacher can create titles and headings as organizers or ask the learner to create a title or heading. When the instructor provides the actual relationship, it should be done in a manner that will direct attention. One way to do that is to relate those connections to ideas that are highly relevant to the learner. They should capture attention *and* motivate learners to think actively about the information. Wittrock advises that even though the instructor makes connections for the learners, learners must make those connections actively themselves to learn them. Passive observation will not suffice.

Given that there are many types of relationship-building activities that can be selected, a guide for selecting from among those activities is appropriate. Although Wittrock claims that levels of thinking are not represented in his theory and designates only two types of relationship building, it is evident that, by examining the level of mental effort required for each of these activities, the two categories can be broken down even further. Those activities that relate parts of the information in the environment together include coding, organization, and conceptualization levels of thinking, whereas those that relate parts of the information to prior knowledge include integration and translation tasks. Those activities that relate to the various levels are listed in Table 28.4 (Grabowski, 1995).

28.4 SUMMARY

The recommendations that follow from Wittrock's writings provide straightforward ideas to be implemented by teachers and designers for any instructional medium. Whether we are designing for the computer, print, television, or instructor-led training, face-to-face, or e-learning environments, these principles hold. Engaging the learner in active processing of the information should be our primary goal.

The computer can be exploited as a powerful means to engage learners by tapping its capability as a mental construction tool, rather than as an automated page-turner (Jonassen, 2000). Following Wittrock's principles, one should put the control of learning in the hands of the learner by creating an advisory environment in which learners manipulate information by moving text, graphics, and media segments around mentally or physically, testing their own ideas. This does not mean placing the learner in a total learner-controlled *information* environment but, rather, in one in which success can be guided, rewarded, and reinforced.

Creating a transactive environment (between the learner and the materials) is a greater challenge when designing for more static media, but it can be done cleverly by giving conscious attention to the design of the message to induce thinking—such as "stop and think activities" (Arnone & Grabowski, 1992), incomplete messages, and rhetorical adjunct questions to direct and engage thought.

The second important message from Wittrock is that more time and effort be spent on identifying important factors about the learner than is traditionally spent in the instructional design process. Identifying the learner has always been an important step in the instructional design process; however, how to do this, or what kind of key information to gather, is rarely specified. Wittrock's writings show some clear elements: Gather learners' conceptual preconceptions, preconceptions about their learning the topic, preconceptions about their role as learners, prior knowledge relating to the topic, general prior knowledge, and metacognitive abilities. This information is input into the design phase during which strategies are selected to help learners attribute learning to their own effort and create satisfaction in and control over learning. It also aids in the selection of activities appropriate for learners that engage them in personally generated understandings of the topic. The information also feeds into the actual development following effective message design that gains and maintains attention. During the evaluation phase, designers need to know if the learner actually engaged in the generative activity to be able to interpret effectiveness data. This knowledge, combined with a good understanding of appropriate activities that draw relationships, should result in very effective instruction.

28.5 IMPLICATIONS FOR FURTHER RESEARCH

Past research validates Wittrock's basic premise of active learner engagement; however, further research could help designers select from among the various types and modes of activity and understand the implication of the types of activities on levels of information processing. In other words, we need to ask which generative activities are more appropriate than others, whether they should be used in an instructor-provided format or a learner-generated one, and on what basis designers can make activity selection.

28.5.1 Selection of the Type of Generative Activity

Table 28.4 matches generative activities to desired levels of cognitive processing. This matching must be empirically tested. Questions such as the following take this into account.

1. What are the effects of each generative activity on higher-level learning? Much of the previous research has emphasized fact and concept-level learning and has not dealt with higher-level learning such as application, synthesis, or problem solving.
2. Are there clusters of generative activities that are best used for specific learning tasks or levels of learning? What types of learning tasks are more appropriately coded versus integrated?
3. Are the activities classified appropriately by type of information processing—coding or integration—or can another level of processing be added to the theory to make it more prescriptive?

28.5.2 Use of Generative Activities

Previous research has also indicated mixed results from activities requiring overt/covert responses. Because of the "veto power over learning," described by Rothkopf (1976, p. 94), further research should explore the conditions that may require overt manifestations to ensure that processing occurs.

4. Is there a differential effect from requiring or not requiring overt manifestations of generative activity? What are the best strategies (instructional and mechanical) for ensuring that information is manipulated in the mind?

28.5.3 Motivation, Learner, and Knowledge Creation Processes

Another very significant area of research is identifying strategies that will enhance the perception of learner responsibility. This indicates a need to merge the learner control research with that on generative learning. From Wittrock's writing, it seems apparent that learner control with advisement would be recommended, but it needs to be empirically tested with questions such as the following.

5. What are the best methods for providing advisory feedback on learner-generated conceptions of the instruction content? and What are their effects?
6. What is the effect on learning of directive, embedded, or inductive control when the motivation level varies?

Various researchers have proposed several strategies. Directive control, as defined by Rothkopf (1976), takes the form of directions that are given to a learner to perform a particular task. Embedded strategies are similar to Rothkopf's inductive control in that they may not be obvious to the learner. Inductive control does not force a response, however, whereas an embedded strategy expects the learner to perform the behavior before going on (Rigney, 1980).

28.5.4 Instructor Provided or Learner Generated?

Some of the research results reported earlier indicate that both developmental and cognitive strengths may play a part in selecting appropriate and successful activities. Besides learner-generated activities in which the learner actively makes connections, Bovy (1981) suggests that instructor-provided activities

TABLE 28.5. Theoretical Match of Generative Activity with Cognitive Strengths

Cognitive Style Type	Cognitive Strength	Learner-Generated Activity	Instructor-Provided Activity
	Brendth of Categorization—Organizational Thinking		
	Broad	Create summaries	Provide outlines
		Create main ideas	
	Narrow	Outline	Provide summaries
			Provide main ideas
	Organizational Patterns—Organizational Thinking		
	Global	Create summaries	Provide outline
		Create diagrams	
	Analytic	Create outline	Provide summaries
			Provide diagrams
	Variation in Memory—Organizational Thinking		
	Leveling	Create summaries	Provide outlines
	Sharpening	Create outlines	Provide summaries
	Conceptual Styles—Conceptualization		
	Relational	Create concept maps	Explain/clarify
			Identify important information
			Provide paraphrases
	Analytic/descriptive	Explain/clarify	Provide concept maps
		Identify important information	Provide paraphrases
	Categorical/inferential	Paraphrase	Provide concept maps
			Explain/clarify
			Identify important information
	Cognitive Dimension—Integration		
	Complexity (abstract)	Create analogies	Provide relevant examples
		Create metaphors	Relate to prior knowledge
	Simplicity (concrete)	Create relevant examples	Provide analogies
		Relate to prior knowledge	Provide metaphors
	Thinking Patterns—Organization, Conceptualization, Integration, Translation		
Organizational	Convergent	Creating outlines	Provide summaries
		Creating diagrams	
Conceptualization		Explaining/clarifying	Provide concept maps
		Identifying important information	Paraphrase
Integration		Relate to prior knowledge	Provide analogies
		Create relevant examples	Provide metaphor
Translation		Evaluation	Question
		Analysis	Provide predictions
		Inference	
Organizational	Divergent	Create summaries	Provide outlines
			Provide diagrams
Conceptualization		Create concept maps	explain/clarify
		Paraphrase	Identify important information
Integration		Create analogies	Relate to prior knowledge
		Create metaphors	Provide relevant examples
Translation		Question	Evaluation
		Make predictions	Analysis
			Inference

supplant cognitive connections that are provided for the learner by the instruction itself (instructor generated, not learner generated, but personally relevant). There is also another category of instruction in which no control is provided: offering no suggestions, no forced responses, and no supplanted cognitive strategies. Table 28.5 proposes a matching of cognitive strengths with levels of thinking and recommended generative activities. If the activity is one that matches the cognitive strengths of individuals, then perhaps it should be presented in a learner-generated format. If it is an activity that would frustrate the learner, i.e., it is not a cognitive strength, then it should be presented in an instructor-provided format, so that the mental effort can be concentrated on the meaning of the message, rather than on a frustrated attempt at using a technique that does not match one's cognitive style. Providing no guidance may best be saved for learners with well-developed metacognitive abilities (see Table 28.5).

Research designs should then test the effect of these three presentational strategies (learner generated, supplanted, or no control) for each generative learning strategy matched by cognitive style or other individual difference factors against desired levels of learning or the cognitive processing requirements of the specific task. Cognitive developmental issues should also be considered. The following research questions should yield very important prescriptions.

7. Is there an appropriate use for supplanted vs. generated learning? Does this vary by task or learner?
8. Which activities match with developmental levels of learners?

28.6 CONCLUSION

The principles behind generative learning offer the instructional designer much guidance for developing environments that emphasize the learner as an active partner in the instructional process. Generative activities can be selected based on the type and level of cognitive processing desired. Generative learning theory is not discovery learning but student-centric learning with specified activities for actively constructing meaning. Generative learning activities require internal processing of external stimuli. A generative learning environment is not limited to open-ended resources, although it can engender those, and includes carefully crafted external stimuli that are ready for individual processing. Generative activities are what exist between external stimuli and the learner. Generative learning theory does not assume dominance of the role of the learner or the instructor or instruction, but partnership in the process. As a "practical cousin" to constructivism and a more complete "second cousin" to behaviorism, generative learning theory is easily applied to any learning or instructional setting. The subtle differences between this theory and other theories account for differences in the "where the sage belongs" debate. For behaviorism, the sage is on the stage. For constructivism, the sage is viewed as a guide. For generative learning theory, the *sage, guide,* and *learner* are in the center. Content, instructional expertise, and instructional intention are expected of the sage and guide. Active engagement, attention, and learning intention are also expected of the learner. There is much research that has been done to support this position, and there is much research left to do to establish specific guidelines that help the designer create a learning environment that stimulates attention and intention and promotes active mental processing at all stages and levels of learning. The evidence indicates, in my view, that generative learning theory is very applicable to instructional design and that research defining types of processing should continue.

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