The Proceedings of the International Conference on Creationism

Volume 6
Print Reference: Pages 511-527

Article 41

2008

Mapping Structural Knowledge of Scientific Creationism to Direct Information and Object Structure Design in Planning Textbooks and Educational Materials

Denise A. Wenger

In A. A. Snelling (Ed.) (2008). Proceedings of the Sixth International Conference on Creationism (pp. 511–527). Pittsburgh, PA: Creation Science Fellowship and Dallas, TX: Institute for Creation Research.

Mapping Structural Knowledge of Scientific Creationism to Direct Information and Object Structure Design in Planning Textbooks and Educational Materials

Denise A. Wenger, Ph. D., Instructional Designer, Instructional Materials Depot, Inc.
W244 N4880 Swan Road, Pewaukee, WI 53072

Abstract

A worldview, such as that defined by Institute for Creation Research tenets of scientific creationism, is a cognitive structure or schemata that impacts human information processing and learning. Cognitive research indicates that there is not a physical referent for such structural knowledge in the human brain. But planners and writers of educational materials view structural knowledge or worldview as a useful metaphor for describing how the human brain constructs or structures knowledge. Research indicates that *structural knowledge* is tied to memory processes, problem solving, learning, and knowledge acquisition. This paper focuses on the use of mapping techniques to plan and design instructional experiences for materials or programs intended to advance learners' development of structural knowledge (worldview) presented in the Institute for Creation Research tenets for scientific creationism.

Keywords

Worldview, Cognitive mapping, Structural knowledge, Scientific creationism, Information design, Mental chronometry, Object design, Textbook planning, Implicit methods, Elaboration theory, Frames and slots, Explicit methods, Semantic maps, Causal interaction maps, Concept maps, Graphic organizers, Learning strategies, Knowledge acquisition, Content structures, Text evaluation, Content structure analysis, Evaluation design, Visual rhetor, Constructivist design, Scenarios.

Introduction

Structural knowledge refers to how information within a knowledge domain is organized. It describes *how* declarative knowledge (concepts of objects, events or ideas) and procedural knowledge (processes and performances) are interconnected. Structural knowledge also is known as *cognitive structure,* the pattern of relationships among knowledge in memory. Some researchers regard cognitive structure as an integral component of an individual's personality that accounts for differences in an individual's behavior and response to an environment. They think that individuals actively revise how they integrate and organize knowledge as they experience an environment. How they organize their cognitive structures (that is, the patterns and relationships they form), determines how they interact with and behave in their environment.

Researchers see all knowledge as having inherent structure and structural knowledge as the component of knowledge that defines the structure-based relationships between concepts in memory (whether the concept is concrete or abstract or represents declarative knowledge or procedural knowledge).

Within this paper, worldview is defined as structural knowledge. It is cognitive structure that integrates and interrelates knowledge from the perspective of individual experiences. It can be represented using cognitive mapping and process tracing techniques.

For teacher-designers of instruction, research on the relationships between structural knowledge and the development of specific mental abilities, such as memory, problem solving, learning and knowledge acquisition, can inform teaching and design practice. Such research makes a difference in the selection of heuristics for problem solving and/or learning strategies. It makes a difference in the planning of experiences for constructing structures in the content areas, the designing of learning experiences, or the developing of diagnostic tools to assess needs or progress toward goals. By viewing the Institute for Creation Research tenets of scientific creationism as a learning object (to programmers, a unit of encapsulated data) and mapping patterns of relationships between tenets, a teacher-designer can visually depict relationships and expand understanding of the structure of knowledge involved with worldview construction. This understanding can be used to select methods, implicit or explicit, for conveying structure in the design of programs in a variety of formats.

It is with the needs of constructivist teacher-designers in mind, that this paper takes an inductive approach to discussing the design of information and object structure in planning instructional materials and programs. The paper takes the reader on a journey that fosters development of knowledge structures for constructivist design. During this journey, we review research that focuses on the relationships between structural knowledge and memory structures, problem solving, learning strategies and knowledge acquisition. Next, we infer from research a set of ten constructivist design principles. Finally, we apply the design principles to map content patterns for the Institute for Creation Research tenets of scientific creationism (object design) and processing patterns for building structural knowledge. Institute for Creation Research tenets of scientific creationism used for mapping appear in the Appendix.

Step 1: Concept Formation, Research on Structural Knowledge

Cognitive research has much to say about how the construction of memory, problem solving abilities, learning, and knowledge acquisition is related to structural knowledge. These subjects have been the focus of cognitive research for a century. But only in the last two decades have cognitive research, neuroscience, and structure of knowledge research come together to recognize the *generative* nature of learning processes of the brain. Jonassen, Beissner, and Yacci (1993) suggest that structural knowledge is inherently *constructivistic* because it represents relationships between concepts that change within the context in which they are constructed.

Wittrock (1992) provides a functional model of learning from instruction. This model builds upon knowledge about brain functions and focuses on learning as a process that generates relations. Within Wittrock's model, generative processes are the learning processes that learners use actively and dynamically to selectively attend to events and generate meaning for events by *constructing relations* between new or incoming information and previously acquired information, conceptions, and background information. These active and dynamic generations lead to reorganizations and re-conceptualizations and to elaborations and relations that increase understanding. Generative processes include *learning* processes, such as attention; *motivational* processes, such as attribution and learner interests; *knowledge creation* processes, such as preconceptions, concepts, and beliefs; and *knowledge generation* processes, such as problem solving, analogies, metaphors, and summaries (Wittrock, 1992).

Wittrock (1992) describes how neural systems, as generative systems, receive, selectively attend to and integrate multi-sensory information. Learners do not store information verbatim, he says. Memory reflects mood (emotions), context, and intention at the time of recall. Memories consist of *patterns of associations* within a network of neural nodes and connections. Learners acquire concepts and nodes indirectly and inductively by repeated experiences with similar events. Wittrock describes how neural systems work:

Neural systems show self-direction, self-control, motivation, and arousal. They receive, selectively attend to, and integrate multi-sensory information. They relate multi-sensory information to knowledge, experience, intentions, and purposes, all of which are sources of control that regulate the construction of meaning. From this synthesis, they generate meaning and significance. They also involve metacognitive activity. They construct context-specific learning strategies and plans that regulate motor responses and that adapt to a perceived and constructed reality. They learn, and they modify their future operations. They do not passively receive and record information. They are generative systems (Wittrock, 1992, p. 335).

It is the primary function of the brain to generate a model or models that make it possible for us to make sense of the many events we experience, says Wittrock. These models help us understand *why* things are happening. This understanding leads to predictions of *what* is likely to happen in the future and *how* we can exert some control and direction over the future. But learning and the generation of models is not a passive recording of information; it consists of *active generation* of meaning (Wittrock, 1992, p. 335).

Anderson and Schooler (1990) used a rational analysis process to establish a *causal* link between the structure of the environment and the structure of memory in different knowledge domains. They concluded that memory structures can be ascertained from analysis of environmental knowledge structures and that such analysis can make knowledge of a structure more accessible for learners. They suggested that the construction of specific knowledge structures is demand-driven. In other words, it is the knowledge structures encountered in the environment that *cause* the structure of memory to change. Changes in cognitive knowledge structure (memory) are directed by demands of the environment; changes reflect the knowledge structures encountered or experienced in the environment. (Anderson & Schooler, 1990)

Structural knowledge and memory

Cognitive research indicates that there is not a single, physical referent for such structural knowledge in the human brain or a single area where such knowledge is stored. But cognitive researchers view structural knowledge as a useful metaphor for describing what the human brain knows and remembers.

Kolb and Whishaw (1990, p. 526) note that memory is generally accepted by neuropsychologists as a process that is not observed but is inferred from behavior. Neurologists say that memories constructed by sensory experiences represent a change in brain structure. Both agree that there is not one place in the brain that they can point to and say, this is *where* memory was built and resides in the brain. They conceive of memory as the flow of activity in a given neuronal loop where the synapses in a particular path become functionally connected to form a cell assembly (Hebb's theory). But the use of memory for *remembering* is not defined as the re-excitement of previous experiences in the neuronal loop; it is viewed as a process of *active reconstruction*, a new construction built out of an active mass of past experience and detail that is encoded in image or language form within the brain.

This conceptualization of remembering as reconstruction is particularly important to neurologists seeking to understand the pathology of memory and for teacher-designers seeking to understand the variations they observe in productions that come from memory (that is, feedback of knowledge or creative products). Neurologists know that apparent errors in products from memory could result from disorders or problems in memory storage or from the reconstruction of sensory experiences. After a long delay between experience and reconstruction, for example, remembering may correctly reconstruct experience but incorporate additional elements that, though compatible with the stored sensory experience, are erroneous because they were not part of the original memory (Kolb & Whishaw, 1990, p. 527).

During the last century, memory research demonstrated that concepts established with any sort of structure are better recalled than unstructured lists of concepts. The more semantically meaningful the relationships between concepts or ideas are, the better they are recalled. Consider, for example, the structural knowledge for "telling a story." Story schema in the environment reflect the structure or grammar for "telling a story" and establish how concepts within the story are interrelated. Repeatedly, the learner experiences the structure for "telling a story." It is the story structure that exists in the environment that is mirrored in the learner's memory. When reading a story, the schema for story structure is accessed. As the story is told, the slots for story schema are filled in. As the learner fills the slots with each new story, the learner's cognitive structure is changed. It is reorganized to reflect, with fidelity, the structure that the learner experienced in the environment. When asked to recall or assess a story, the learner relies on his/her experience to recall the story (Mandler, 1983).

Shavelson (1972) says that within the brain, understanding of structure is constructed or reconstructed with each schema encountered in the instructional environment. During the process of learning, the learner's cognitive structure changes to correspond more closely with the structure of the content or with the structure of the teacher's knowledge structure. Thus, at the end of instruction, the learner's structural knowledge is more similar to the structural knowledge of the content or the structural knowledge of the teacher than at the beginning of the instructional experience (Shavelson, 1974). Researchers Anderson and Schooler (1990) say, "human memory mirrors with a remarkable degree of fidelity the knowledge structure (worldview) that exists in the educational environment."

Structural knowledge and problem solving

An extensive body of research focuses on development of cognitive structures for problem solving. Research shows that structural knowledge is integral to performing higher thinking processes, including problem solving. Mayer (1992) analyzed processes used to solve a wide range of different kinds of problems. He noted that thinking for problem solving involved processes by which the learner restructures problems. He examined problem-solving processes from a rule-based systems approach and described thinking as *mental chronometry*, a series of mental operations or stages of processing on a solution path.

A growing body of research on problem solving links the acquisition of structural knowledge to problem solving performance. Research shows that the knowledge structures of expert problem solvers differ from the knowledge structures of novices. Experts have more complex structural knowledge than novices and they represent problems in different ways than novices do. For example, experts initially abstract and apply specific principles to solve a complex problem, while novices focus on literal aspects of the problem. Mayer (1992, p. 393) suggested that a novice has a naive view of problems, a view that focuses on surface features that are not meaningfully related to the concepts for the problem domain. By contrast, an expert looks at the same problem, relates it to a meaningful context and then relates features to concepts contained in the problem. As a result, the solutions of experts differ from the solutions of novices. Both experts and novices are able to categorize problems, but they differ in the quality of their categories. Novices categorize problems based on surface features (that is, *surface* similarities), but experts abstract from surface features and form categories (that is, *structural* similarities) that are tied to solution plans (Mayer, 1992, p. 395).

Today, steps in cognitive processing are used by designers as the basis for analysis in planning requirements for computer-based systems that represent sequences of functional behaviors (scenarios) needed to solve problems (Love, 1993). Software designers map the problem domain in terms of the data (information) and the functional operations (scenarios) that the learner's mind must engage in to solve that type of problem (Love, 1993). Thus, the design of a learning sequence that models inductive reasoning (as a problem-domain), would step the learner through the thinking processes required to solve a problem inductively. Seidewitz and Stark (1995) suggest that in such models, pure procedure will always produce the same sequence of functional operations.

According to Joyce and Weil (1986), a module designed to teach inductive thinking structures the problem-domain to engage learners in specific steps of processing for inductive thinking: Step 1: *Concept Formation* (three subroutines, scenarios): enumeration or listing; grouping, and categorizing. Step 2: *Interpretation of Data* (three subroutines, scenarios): identifying critical relationships, exploring relationships, and making inferences. Step 3: *Application of Principles* (three subroutines, scenarios): predicting consequences or hypothesizing; explaining and/or supporting predictions; and verifying the prediction (Joyce & Weil, 1986, p. 53).

Research on problem solving indicates that not all learners are able to solve all types of problems. Norris and Ennis (1989) found that learners are best able (know the steps) for solving problems for which they have knowledge structures. Solvable problems are those that they previously encountered in the environment and have the cognitive structure to solve. In 1992, the author found that experienced teachers enrolled in a graduate-level critical thinking course were not able to solve all the types of problems on the *Ennis' Critical Thinking Inventory* (Norris & Ennis, 1989). During analysis of their errors, teachers found that they solved types of problems that they had prior experience with. After reviewing the structure of test problems and the heuristics (steps of process) required for correct solutions, teachers were able to solve problems that they previously found unsolvable.

Robertson (1990) used think-aloud protocols to assess cognitive structure and found that the existence of relevant structural knowledge was a strong predictor of how well learners would solve transfer problems on a written exam in physics. He concluded that cognitive structures that connect the formula and important concepts in the knowledge base are important to understanding physics principles. This and other research indicates that domain-specific problem solving relies on adequate structural knowledge of the ideas in the domain under study (Jonassen, Beissner, & Yacci, 1993, p. 10).

Swanson, O'Connor, and Cooney (1990) used think-aloud protocols to examine the *qualitative* differences between expert and novice teachers in solving classroom discipline problems. They found that expert and novice teachers differ in their solutions and statements about mental processes used. Novices organize problems around the literal events given in a problem statement (that is, the physical properties of a situation). Experts develop a principled representation of their thought processes and an ability to recognize patterns. Experts define the problem and evaluate the heuristic routine compared to other heuristic routines. Novices were primarily concerned with problem solution rather than systematically testing possible solutions; their problem solving reflected a need to find a solution rather than to systematically define the problem. Based on their findings, Swanson, O'Connor, and Cooney recommended that strategies and heuristics for solving problems be taught to teachers to improve their abilities to solve classroom problems.

The author employed the design and analysis used by Swanson, O'Connor, and Cooney (1990) to study differences in the use of problem solving heuristics and strategies by people in different age groups. Three groups of teachers asked learners in elementary, secondary, college age, adult and senior age groups, to solve four problems out loud, then the teachers indexed the reasoning used by respondents, using definitions for sub-processes used by Swanson, O'Connor, and Cooney. Sub-process scores were related to sub-processes for three heuristics: *Defining the Problem, Data Acquisition*, and *Organization* and six strategies: *Basic Problem Solving, General Problem Solver, Hypothetico-Deductive, Pattern Extraction*, and *Evaluation and Feedback*. Teachers added a sub-process for feelings. The study was repeated each fall for three years, with different teacher-researchers and different respondents.

All three teacher-researcher groups found that use of problem solving strategies increased from elementary through college years then decreased in adult and senior years (in a bell curve). Use of heuristics for *Defining the Problem* and *Organization* followed the same bell curve as problem solving. But heuristics for "identifying data needed" were used during elementary and secondary school, and then disappeared from use. Use of the *Hypothetico-Deductive* strategy (if-then thinking) increased steadily through college, dropped in adults, and then increased among seniors. Emotional responses increased from elementary to college groups, where they peaked, then dropped in adult years and increased again to secondary-age level highs (Wenger, 1993). Based on study results, teachers recommended that strategies and heuristics that are seldom used and steps of the inductive process be cued during instruction designed to engage learners in scientific processing (Wenger, 1993).

Swanson (1993) used think-aloud protocols to assess whether processing differences between ability groups are based on problems of representation (that is, using a sufficient number of components, a *quantitative* processing problem) or on uses of mental processing structures (that is, using specific strategy subroutines, a *qualitative* processing problem). Swanson found that gifted, average-achieving, and disabled learners did not vary in problem representation, the *quantity* of components used or in the *quantity* of steps toward solution. They differed in the use of subroutines (*quality* of processing). In addition, he found that the ability groups differed in the correlation patterns linking metacognition (knowledge of one's own processing) with mental processing and solution finding. The most academically proficient learners, coordinated mental processes for problem solving with metacognition (Swanson, 1993).

Gagné (1985) and a number of other researchers provide a great deal of evidence that the strategies needed to solve different types of problems can be learned and when learned, can be transferred to new similar problems in different contexts. But critical thinking research indicates that transfer of knowledge structure to problems in different contexts does not happen automatically but is best accomplished at the time when strategies are learned.

Swartz and Perkins (1990) recommend extended practice for transfer. They said, "Reflective and deliberate practice based on a blending of a metacognitive awareness of the appropriate forms of thinking to be used and reflection on new and varied examples is well-researched as an extremely effective classroom strategy in teaching thinking" (Swartz & Perkins, 1990, p. 85).

Structural knowledge and learning strategies

Siegler and Jenkins (1989) examined how people discover new strategies. They found that the process of strategy construction takes place over time; and that sometimes the process takes only a few seconds or minutes, but other times, it takes weeks, months or years. They break the process of strategy construction into two periods: an initial period of strategy *discovery*, and a later period of strategy *generalization*. While the discovery period may involve a sudden "aha" experience that changes the mind from not knowing to knowing, the first use of a strategy in a domain is not the end of the strategy construction process. Both the strategy discovery and generalization processes represent a series of qualitative and quantitative changes as the strategy is used in different contexts and the learner gains insights into the nature of the strategy and the problems solved. According to Siegler and Jenkins, "a person has not fully constructed a strategy until the person extends it to the entire range of situations in which it is useful."

Gagné (1985) focused on how prior knowledge aids discovery of new strategies in complex domains, particularly mathematics. He found that by acquiring and using internally directed processes, *cognitive strategies*, learners were able to regulate such internal processes as attending and perceiving, encoding incoming material for long-term memory, retrieving information, and solving problems. He found that most cognitive strategies are established or activated by verbal instructions. Simple strategies may take the form of simple rules (for example "say it to yourself" and "say it several times"). For complex strategies that relate to complex procedures, the internal requirements require that the learner deal with certain task-relevant concepts such as the "measure of an angle" or "geometric relations." But the internal requirements again are simple rules, such as: "begin at the end and work backwards" or "split the problem into parts" or "be prepared to switch your approach" or "group the ideas into categories" or "break the problem into its natural parts."

Shaughnessy (1977) focused on the patterns of errors that writers make as they produce print (text) or narratives. "Errors are unintentional and unprofitable intrusions upon the consciousness of the reader," said Shaughnessy.

> They shift the reader's attention from where he is going (meaning) to how he is getting there (code) … All codes become codes by doing some things regularly and not others, and it is not so much the ultimate logic of these regularities that makes them obligatory but rather the fact that, logical or no, they have become habitual to those who communicate within the code.

After identifying patterns of errors in basic writing, the teacher-designer can systematically design instruction to help learners eliminate error patterns. Based on research in the teaching of writing, Shaughnessy recommended that writing assignments aim at developing the learner's perceptions of rhetorical structure; at introducing accurate patterns (content structures) that are familiar (that is, story narrative pattern, historical event pattern, or a laboratory experiment pattern); and at instantiating error-free codes by providing multiple assignments that focus on the targeted rhetorical structures or patterns that need attention.

Gorrell (1982) focused on giving basic writers repeated success through controlled composition techniques. She coordinated use of imitative writing practice with original, self-generated writing of model compositions. Controlled composition (strategy) frees the learner from idea generation and expression tasks and enables correct formation of these troublesome forms, says Gorrell.

Langer and Applebee (1987) used think-aloud protocols to examine how knowledge and understanding are affected by the print/writing activities that learners engage in after reading. They found that the more that content is manipulated, the more likely it is to be remembered and understood. They found that analytic writing tasks focus learners on a specific body of information and on the relationships that give structure and coherence to information. In the context of learning from print/text, they found that analytic tasks lead to better retention of a smaller body of information; and they suggest that such tasks should be the tasks of choice when the emphasis is on concepts and relationships (in a context) and where these relationships are more important than memory for a large body of facts (Langer & Applebee, 1987, p. 36).

Helmers (2004) analyses the structure of the fine arts, including sculpture, painting, pottery, textile design, drawings and prints, as structural knowledge, using a framework called visual rhetoric. "A visual rhetoric is a frame for analysis for looking and interpreting. A rhetoric of the visual abstracts both text and image to the level of signs," says Helmers. "It is the message and the act of communication that is more important than the medium … rhetoric does not focus on correspondences between the arts, but on the image itself as a carrier of meaning," says Helmers (2004, p. 64). Visual rhetoric is inquiry-based spectatorship, a method for studying and interpreting the fine arts, says Helmers. It depends on an inductive process of accrual in which past experiences merge with new visual and/or narrative evidence to construct meaning. That meaning will change over time as the event is recalled and the image is revisited in different settings or contexts, says Helmers.

"Argument, in the traditional sense, can be readily visual," says Blair (2004, p. 59). The visual adds drama and force of a much greater order that the written word. The visual has immediacy, a verisimilitude. It has a concreteness that can help influence acceptance in ways that are not available to verbal communications. While persuasive, visual arguments tend to be one-sided. Qualifications and objections are not expressed in the visual argument. But where visual arguments excel, says Blair, is in the rhetorical dimension. He says:

> In communicating arguments visually, we need to attend particularly to the situation of the audience. What is the setting and how does it introduce constraints and opportunities? What visual imagery will the audience understand and respond to? What historical and cultural modes of visual understanding does the audience bring to the situation? Visual arguers will answer these questions in creating their visual enthymemes, thus drawing the viewer to participate in completing the construction of the argument and so in its own persuasion. When argument is visual, it is, above all, visual rhetoric (Blair, 2002, p. 59).

Joyce and Weil (1986) provide a review of the steps of mind (thinking processes) that the learner engages in when using different teaching/learning models. Their review includes several models that can be used by designers who seek to build cognitive structures to support a creation science worldview, including *attaining concepts, thinking inductively, causal reasoning, science inquiry, synectics, group investigation, jurisprudential inquiry, laboratory training, direct instruction* and *simulations*.

Joyce and Weil (1986) analyze each of these teaching/learning models or strategies in terms of instructional syntax. They delineate the steps of process (called *scenarios* by computer systems designers) that should be built into a learning sequence designed to teach each part of each model. In addition, they classify each teaching/learning model according to the amount of cognitive structure it provides to the learner on a dependent-independent continuum. According to Joyce and Weil, the prescriptive selection of teaching/learning models is one of the most important roles that the teacher-designer plays in planning curriculum. The teacher-designer must match the learning environment (represented by the model) to the cognitive complexity for learning so that the selected model increases the complexity of the learner's internal structure and moves the learner progressively from teacher dependence to independence in learning process (structure).

Structural knowledge and knowledge acquisition

In their text, *Structural Knowledge, Techniques for Representing, Conveying, and Acquiring Structural Knowledge,* Jonassen, Beissner, and Yacci (1993) review mapping techniques for acquiring knowledge and report on verified techniques for *implicitly* and *explicitly* conveying the structure of content. They define content structures as "writing plans that are used to determine the sequence and content of instruction to promote understanding of the author's perspective on the content area" (Jonassen, Beissner & Yacci, 1993, p. 101). Because of their relevance to discussion of constructivist instructional design, two methods for *implicitly* conveying knowledge structure (*content structures* and *frames and slots*) and four methods for *explicitly* conveying knowledge structure (*semantic maps, causal interaction maps, concept maps,* and *graphic organizers*) are detailed below. During Step 3 of this paper, these methods are used to outline relationships between Institute for Creation

Research tenets for scientific creationism.

Content structures are implicit methods of conveying the structure of content. Through analysis of prose, Meyer (1985) identified five types of *content structures* that are frequently used in text: description, collection, causation, problem/solution, and comparison. To convey meaning effectively, a writer imposes a content structure on a topic and creates a *linear* flow of text. Through textual and/or semantic cues, the writer reveals the relationships between ideas. Based on the content area and topics to be covered, the writer develops a writing plan that emphasizes one content structure for the text. By staying faithful to the selected plan, the writer provides a structurally satisfying experience for the reader.

The success of text in conveying information and building structural knowledge for the content area depends, in part, on how well the text is organized (Jonassen, Beissner & Yacci, 1993). When text is organized so that students can construct graphic representations of what they read, researchers find that students better understand which ideas are important, how they relate, and what points are unclear (Jones, Pierce, & Hunter, 1989). Research shows that when text is organized in a coherent manner, readers can process the text more rapidly and remember more of what they read (Meyer, 1985).

Jones, Pierce, and Hunter (1989) used graphic representations as visual illustrations of verbal statements (that is, flow charts, pie charts, and family trees) to illustrate the "frame" for content or knowledge in different subject domains. They identified the underlying organizational schema for text and drew graphic representations to help learners acquire knowledge, comprehend, summarize, and synthesize complex ideas and relationships in different subject areas or contexts. They found that reading with an appropriate graphic structure in mind helps students select important ideas and details as well as detect missing information and unexplained relations. By constructing and analyzing a graphic, they found that students became actively involved in processing a text and expanded their nonlinear thinking. They found that unlike prose summaries and linear outlines, spider maps and matrices could be read left to right as well as top to bottom, thereby providing in-depth processing and rich contextual associations within the learner's cognitive structures. They found that such graphic representations provide content in two modes of processing, visual and verbal modes.

Frames and slots provides a data structure for organizing stereotypical events or situations in memory. Frames are an implicit method for organizing text in various disciplines. Frames provide a general outline for a discipline's structure. Each frame is organized with specific information attached to it, and slots supply categories of information within that frame. Thus, frames provide the organizational structure on one dimension, and slots hold the main ideas or key points of information about the subject area on the other dimension, organized in a matrix format. This organizational method often is used as a means of organizing chapters in a textbook; each chapter presents information in the same order so that a reader develops a schema (a structural outline) for understanding the content area, and subsequent chapters reinforce that structural knowledge. Use of frames and slots helps learners organize their thoughts and develop structural knowledge for a subject area and helps teachers construct test items that focus on main ideas (Jonassen, Beissner & Yacci, 1993, pp. 126–129).

Semantic maps use a graphical format to explicitly convey hierarchical relationships between concepts in a content area. They are used to categorize concepts and classify or group them according to common features. In a semantic map, categories of related concepts are named and form a three-tier hierarchy of concepts related to the central concept or idea. Semantic maps are used effectively for vocabulary instruction. As a pre-reading activity, they can serve as an advance organizer, introducing important ideas or concepts included in a reading. As a post-reading activity, they can be used to check understanding and clarify relationships between ideas. Research shows that construction of semantic maps helps learners make hierarchical relationships between ideas explicit as they build complex cognitive structures (Jonassen, Beissner, & Yacci, 1993, p. 137).

Causal interaction maps provide explicit graphical representation of causal and correlational relationships between observed and unobserved variables such as the steps and processes used for problem solving or the causal relationships between ideas or knowledge structures in a content area. This form of mapping can be used to represent causal relationships between tenets of a worldview. For designers, causal interaction maps can be useful tools for anticipating, in graphical format, testing requirements for content and structural knowledge relationships that could be the focus of assessments or statistical analysis such as multiple regression analysis, a statistic that measures the strength of the relationships between content variables (Shavelson, 1988, pp. 164–165).

Concept maps are two-dimensional diagrams that explicitly illustrate relationships between ideas/concepts. They are organized hierarchically with the most inclusive concept at the top of the page and subordinate, least inclusive concepts at the bottom of the page. They use labeled lines to depict relationships between concepts and multiple lines to depict multiple relationships. Learners can use concept maps as a study guide or to review material in a subject area, to identify relationships between concepts, and/or to foster creativity. It can be used as a substitute for outlining, as a prewriting (brainstorming) activity, and as a mapping tool for critical analysis. Designer-teachers can use concept maps as a curriculum development tool to help identify areas that need to be included in instruction and/or assessment following instruction. Research indicates that this is an effective testing method for identifying learners' progression in the attainment of differentiated and organized structural knowledge (that is, to assess how closely the learner's structural knowledge resembles that of the expert or teacher) (Jonassen, Beissner, & Yacci, 1993, p. 157).

Graphic organizers or structured overviews are explicit graphic diagrams that provide a general framework for concepts and signal the structure of the material that is to follow. They provide an advance organizer, a structured overview and cue learners for the structure of knowledge that is coming. They frequently are used to convey the organized structure of a course, a class or a lesson, to promote recall and stimulate connection to the text that follows. For learners, graphic organizers or structured overviews provide ideational scaffolding for the ideas to come in the text. According to Jonassen, Beissner, and Yacci (1993, p. 137), "this process communicates the author's or teacher's conception of the information structure."

In testing for knowledge acquisition, structural knowledge provides the basis for separating a domain into its basic parts and constructing test items to measure learning. Mislevy, Steinberg, and Almond (2002, p. 99) note that design principles used to construct standardized tests focus on the essential problem of how to draw inferences about what a learner knows, can do, or has accomplished, based on limited observations of what the learner says or does. Testing research focuses on evidence-centered test design. Tests are designed for some purpose: for placement, diagnostic feedback, administrative accountability, guidance, licensing or admissions decisions, or for a combination of purposes. The questions that appear on the test are designed to provide evidence to distinguish learners with different levels of proficiency, essential characteristics of behavior, or performance abilities that demonstrate the knowledge and skills of interest to the tester. For the test designer, how knowledge is structured and what is considered evidence helps guide the construction of tasks and the evaluation of outcomes (Mislevy, Steinberg & Almond, 2002, p. 99).

Norris and Ennis (1989) discuss assessment design techniques that can be used to gather quality information about learners' thinking, including multiple-choice tests, constructed-response tests, direct classroom observation, individual interview with students, and journals. These researchers contend that thinking is a *process*, and testing for thinking must emphasize the *process* over the *products* of thought. In designing thinking tests, they recommend that the test designer first identify the purpose for the test. Will it be used to test for thinking in a specific subject? Will it be used for formative or summative program evaluation? Will it be aspect-specific or comprehensive? Will it be *norm-referenced* (that is, providing scores that are interpreted by comparing the learner to other learners), or *criterion-referenced* (that is, providing scores that are compared to a satisfactory standard of performance that is set in advance)? Second, they recommend that the designer decide what aspects of thinking processes need to be included in the test? To accomplish this, the designer prepares a *table of specifications*, a table that lists the aspects or components to be tested and the relative weighting that will be applied to each component. Third, the designer begins drafting items, following rules of item writing, for each of the components included on the test. To assist with this process, they provide detailed instructions on how to write multiple-choice tests, develop open-ended information-gathering techniques, and make decisions from testing information (Norris & Ennis, 1989, pp. 101–173).

Step 2:
Interpretation of Data, Principles from Research

In our journey into constructivist design, we now revisit the research cited here and infer from it a set of constructivist design principles for mapping structural knowledge within the learning environment. As a teacher-designer, you can actively transfer the process of constructing design principles from research, modeled here. To infer design principles, reread or scan the research, then think about principles you can derive from that research. Consider how a design principle might be used in designs you are planning. Using the process modeled here can help you generate additional research-based design principles for constructivist design.

Based on research by Wittrock (1992) and Anderson and Schooler (1990): If generative processes, such as learning, motivation, knowledge creation, and knowledge generation are what learners use to construct relationships and changes in cognitive knowledge structure (memory) are directed by experiencing knowledge structures in the environment, then knowledge structures, including tenets of a worldview, must be in the environment in order to be experienced. *Design Principle #1: Construct instruction so that generative processes, such as learning processes, knowledge creation* *processes, knowledge generation processes, and targeted knowledge structures (worldview tenets) are built into the learning environment so that learners can experience and reflect those structures in their memory structures.*

Based on Kolb and Whishaw (1990) on memory: If memory is a functionally connected assembly of neurons and remembering is an active reconstruction that can be changed by delayed use, then prompt and frequent assessment would serve as a more accurate indicator of progress than delayed assessment. *Design Principle #2: Follow instruction with prompt and frequent recall or reconstruction experiences to obtain accurate reports (assessments) from memory during and after instruction.*

Based on Mandler (1983) and Shavelson (1974) on memory: If learners reorganize the schema structure according to experiences in the environment and incorporate the structural knowledge of the teacher, then it is important that the story structure be presented accurately in the environment and that teachers hold accurate structural knowledge for content. *Principle #3: Design instructional experiences so that information is accurately conveyed during instructional experiences and prepare teachers with adequate and accurate structural knowledge for teaching content-area schemas.*

Based on Mayer (1992); Love (1993); Seidewitz and Stark (1995); Joyce and Weil (1986); Norris and Ennis (1989) and Robertson (1990) on problem solving: If structural knowledge plays an integral role in acquisition of problem solving skills, and solutions by expert and novice problem solvers differ based on how they model problems (use abstract principles vs. literal characteristics), then instruction in the mental chronometry (mental operations or stages of processing) should be included in instruction focused on developing problem solving abilities. *Design Principle #4: When teaching learners how to solve different types of problems, include instruction in the mental operations or steps of processing (scenarios) for the different kinds of problems that are the focus of instruction.*

Based on Swanson, O'Connor, and Cooney (1990); Wenger (1993); Swanson (1993); Gagné (1985) and Swartz and Perkins (1990): If differences in the processing patterns between novice and expert problem solvers are due to differences in the use of subroutines (quality of processing) and use of metacognitive strategies, then by increasing knowledge of subroutines related to systematic problem solving, steps toward solution, and strategies for metacognition, the quality of novices' mental processing can be improved with instruction. *Design Principle #5: To improve mental processing during problem solving, include instruction on use of heuristics and strategy subroutines, steps required for problem solution, and use of metacognitive strategies in the content of instruction.*

Based on Siegler and Jenkins (1989); Wittrock (1990) and Gagné (1985) on learning strategies: If strategy construction takes time and includes periods of discovery and generalization that involve qualitative and quantitative changes based on use in different contexts, and the learner does not fully construct a strategy until it is extended to the entire range of situations in which it is useful, then strategy construction (structural knowledge) should be a focus of instruction across time, in different contexts, and in a wide range of situations. *Design Principle #6: Allow time for construction of strategies or new conceptual frameworks during instruction, teach simple verbal commands or rules, and plan scaffolded learning experiences in different contexts and environmental situations to extend complexity of structural knowledge for each strategy or framework.*

Based on Shaughnessy (1977); Gorrell (1982) and Langer and Applebee (1987) on learning strategies: If patterns of error can be identified in a production like writing, then the teacher can design instruction to help learners correct patterns (content structures) and eliminate errors that exist in patterns. *Design Principle #7: Looking for patterns of errors in productions is a strategy that can be used to design instruction to help learners analyze writing or visual art, correct patterns, and eliminate errors in productions.*

Based on Helmers (2004); Blair (2004) and Joyce and Weil (1986) on frames of analysis and learning strategies: If the steps of learning involve processing patterns that can be represented as teaching/learning models and the structural supports (steps of process) supplied by different models are known, then the teacher-designer can work prescriptively to plan instructional sequences to match needs of learners for learning structure and to scaffold learning models/ experiences to provide support that moves dependent learners into independence as learners. *Design Principle #8: Use knowledge of learning models to plan instructional sequences that match needs of learners for learning structure by scaffolding learning (model) experiences in curriculum so that learners have experiences that build them into independent learners.*

Based on Jonassen, Beissner, and Yacci (1993); Meyer (1985) and Jones, Pierce, and Hunter (1989) on knowledge acquisition: If mapping techniques and visuals can be used to frame content, acquire knowledge and (implicitly and explicitly) convey the structure of knowledge for writing plans, then these techniques can help identify the underlying organizational schema for text and the sequence and content of instruction. *Design Principle #9: Use mapping techniques and visuals to frame content, acquire knowledge, convey the structure of knowledge, define content structures (writing plans), identify the underlying organizational schema for text and the sequence and content of instruction.*

Based on Mislevy, Steinberg, and Almond (2002); and Norris and Ennis (1989) on assessment of knowledge acquisition: If testing research focuses on evidence-centered test design, and how knowledge is structured and what is considered evidence helps guide the construction of tasks and the evaluation of outcomes, then the teacher-designers should use assessment design techniques that can gather quality information about learners' thinking or knowledge structures, including multiple-choice tests, constructed-response tests, direct classroom observation, individual interviews with students, and journals to assess thinking processes (knowledge structures), products and performances. *Design Principle #10: Design assessments to gather quality information about learners' thinking or knowledge structures, using a variety of assessment formats, including multiple-choice tests, constructed-response tests, direct classroom observation, individual interviews with students, journals that record thinking processes (knowledge structures), and other products and performances.*

Step 3: Application To Content & Processing Patterns

As we continue our journey into constructivist design, we now apply design principles that we derived from research on structural knowledge. During this step of the inductive process, we use the ten design principles for instructional materials or programs intended to advance learners' development of structural knowledge or worldview by teaching the Institute for Creation Research tenets for scientific creationism.

Design Principle #1 says that we should build targeted knowledge structures into the learning environment so that learners can experience those structures, construct relationships, and reflect those structures in memory during assessments of learning progress. In order to accurately reflect the relationships between targeted Institute for Creation Research tenets, teacher-designers must specify the content to be taught and graphically depict or map how declarative knowledge (for example, concepts, events or ideas) are related or interrelated.

By mapping relationships between Institute for Creation Research tenets using implicit and explicit mapping techniques, teacher-designers can frame content, expand understanding of interrelationships between tenets and visually represent the structure of the creationist worldview. After content maps are completed and accepted by the writing community, they can be used systematically and consistently to advance content understanding of scientific creationism in a variety of disciplines and at different grade levels.

Two *implicit* mapping techniques that teacher-designers can use to convey content relationships for Institute for Creation Research tenets of scientific creationism are presented here. Figure 1 provides a *content structure map* that depicts causal relationships between tenets. Figure 2 provides a *frames and slots map* that provides a framework for exploring interrelationships between groups of tenets, those that relate to created forms (tenets 2–5) and those that relate to created generative processes (tenets 6–9). Both mapping techniques can help teacher-designers organize content relating to the Institute for Creation Research tenets for scientific creationism. But the two maps serve different instructional purposes.

In Figure 1, the relationships between the nine Institute for Creation Research tenets of scientific creationism, listed in the Appendix, are presented in a *content structure map.* Tenet 1 focuses on the Creator, and tenets 2–9 focus on created forms and generative processes. Tenets 2 to 9 have a causal relationship with Tenet 1. Thus, Tenet 1 (creator) is the antecedent cause of all created forms, including biological life in Tenet 2 (plants) and Tenet 3 (animals), Tenet 4 (humans) and Tenet 5 (landforms). Tenets 6–9 are related to generative processes and creation, including Tenet 6 (processes), Tenet 7 (change), Tenet 8 (purpose) and Tenet 9 (logic). Each of these tenets also has a causal relationship with Tenet 1 (creator). In this map, the tenets are grouped to reflect their differences in state of being as created forms or as generative processes.

Figure 1 presents the causal relationship between Tenet 1 (creator) and the other tenets. This causal relationship is foundational to Scientific Creationism. It is a relationship that needs to be presented as direct content, using implicit or explicit methods, in printed (text), museum displays, and media publications (see Figure 1).

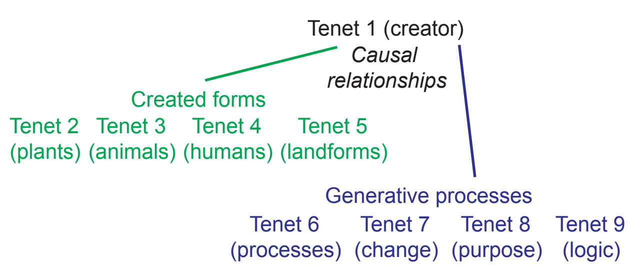

Figure 1. Content depicting causal relationships for Institute for Creation Research tenets.

Figure 1 presents a possible division of tenets for a writing plan discussing the cause and effect relationships between Tenet 1 (creator) and the other tenets, based on their state of being after creation.

In developing a writing plan, another structure that could be used for presenting Institute for Creation Research tenet relationships is the *frames and slots* structure. Here the frame is organized as a matrix with tenets or concepts on the horizontal side and aspects relating to those tenets on the vertical side. The matrix provides slots that detail the relationships at intersections. Figure 2 shows a frame and slots matrix used to display specific aspects of created forms, represented in: Tenet 2 (plants), Tenet 3 (animals), Tenet 4 (humans), and Tenet 5 (landforms). In this matrix, tenets appear on the horizontal axis and specific aspects relating to creation of those forms appear on the vertical axis. Aspects are derived from Tenet 3 and include origin, physical form, function at the time of creation, and changes since creation (see Figure 2).

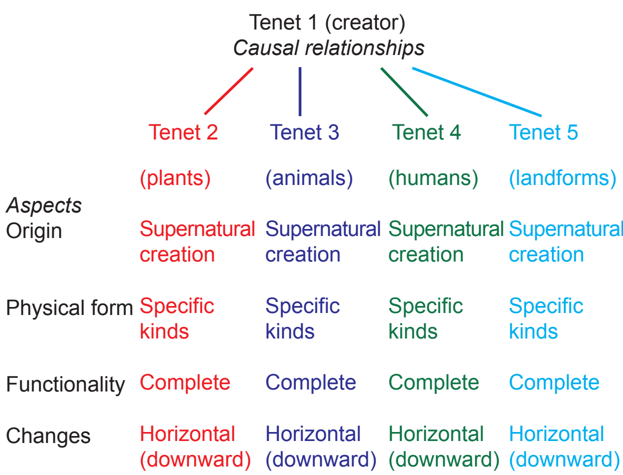

Figure 2. Frame and slots matrix for physical creation.

Using information ordered for presentation in the frame and slots matrix, the teacher-designer works horizontally or vertically through the slots of the matrix. Content reflects the order of the matrix and has a coherent structure that helps learners structure their knowledge and understand the tenets and their aspects. The frame and slots method not only helps organize information for discussion, it also helps the teacher-designer focus on main ideas for assessment. The frame and slots matrix also can be used to structure ideas during essay writing. Or the frame itself can be used during instruction and recreated by learners during a testing scenario at the end of instruction. Note that all the tenets in the matrix have a causal relationship to Tenet 1 (creator).

In Figure 3, the frame presents two categories of tenets, those that relate to created objects, and those that relate to generative processes. Figure 3 shows a frame and slots matrix that could be used to organize material that focuses on created forms: Tenet 2 (plants), Tenet 3 (animals), Tenet 4 (humans), and Tenet 5 (landforms), placed on one dimension of the matrix, and generative processes past and present: Tenet 6 (processes), Tenet 7 (change), Tenet 8 (purpose), and Tenet 9 (logic) placed on the other dimension. Using this map, the teacher-designer can provide information to learners in a consistent order so learners develop a coherent sense of interrelationships between the tenets. This diagram also helps the teacher-designer focus on main ideas for assessment. Note that tenets on the horizontal plane refer to created forms that occupy space, and tenets on the vertical plane refer to generative processes that exist in time. The slots in the matrix represent interrelationships in space and time (see Figure 3).

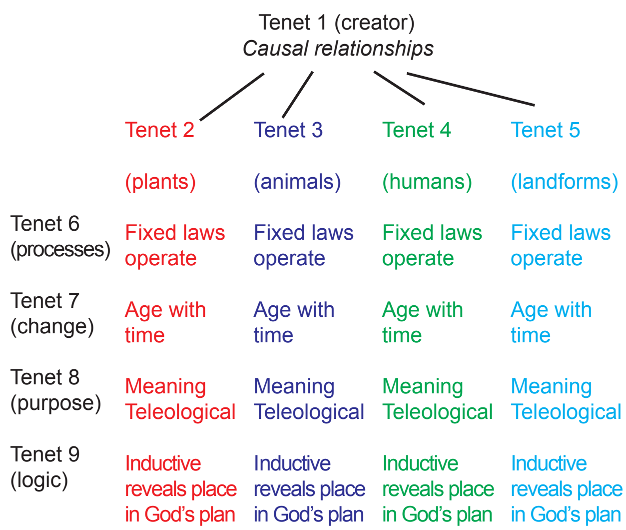

Figure 3. Frame and slots matrix for tenet interrelationships.

Using information ordered for presentation in the Figure 3 matrix, the learner or writer can work horizontally or vertically through the slots of a matrix. By depicting the interrelationships for all the tenets in one matrix, the teacher-designer develops a content organization tool that can be used to organize simple or complex content and bring forward primary interrelationships for presentation and assessment. In preparing content for text, a teacher-designer may focus extensively on slots in one or two columns of the matrix. Or the teacher-designer may focus on one row of the matrix. The frame itself can be used during instruction and can be recreated by the learner during testing at the end of instruction. Note that all the tenets have a causal relationship to Tenet 1 (creator).

Implicit mapping creates an opportunity for designers to define relationships between distinct components (tenets), so that they can focus attention on them separately (and sequentially) in the planning/

writing of educational materials and educational sequences. Because the human mind can only deal with a small amount of information at a time, such modeling of a complex worldview provides a valuable picture or pattern of content relationships that can be used internally to organize content within neural structures. Consistency in the presentation of structure facilitates the building of cognitive structures that "mirror" the learning environment and worldview structure (that is, give coherence and cohesion to the structure).

To visually convey hierarchical relationships for content, the teacher-designer can use an explicit method such as *semantic mapping*. Semantic mapping often take the form of an advance organizer, that is, a graphic that provides a pre-reading or pre-lecture map of the content to be addressed. Figure 4 provides a semantic map for one Institute for Creation Research tenet, using content from slots in Figure 3 for the content for this advance organizer (see Figure 4).

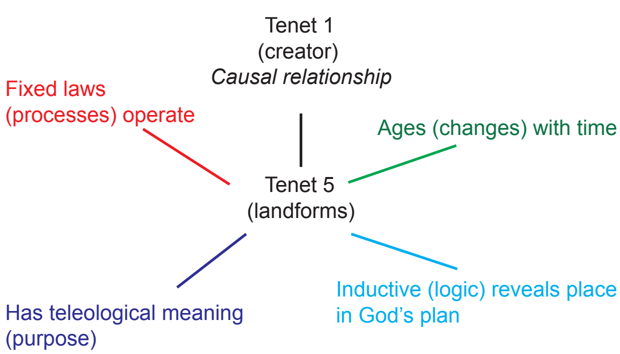

Figure 4. Semantic map for one Institute for Creation Research tenet.

Semantic maps also can be used to provide a content overview for a teaching/learning strategy. In this use, the graphic organizer provides a visual representation of structure that helps the learner conceptualize the structure of the process he/she will engage in.

Using implicit and explicit mapping techniques to frame content, the constructivist teacher-designer can develop a "writing plan" that organizes content and builds structural knowledge patterns for learners of all ages. Consistency in presentation of content helps learners construct memory structures that are similar to the worldview presented by the instructional experience, relate new knowledge to old knowledge, and better recall or actively reconstruct content built by sensory experiences.

Application to Generating Accurate Memory Structures

By mapping content for instructional experiences that graphically display complex interrelationships (as in Figure 3), teacher-designers can plan sets of experiences so that information is accurately conveyed and teachers are equipped with structural knowledge for teaching schemas with consistency in the content areas (as in Design Principle #3).

In addition, sets of experiences can be designed (and mapped) to provide transfer of knowledge to other contexts. Using Figure 3, for example, the teacher-designer can move horizontally through each generative process and examine how one process (that is, hydrologic cycle), influences different life or landforms. Next, the steps of the process can be transferred to another life or landform. In this way, the constancy of processes can be established as students engage in knowledge generation and regeneration experiences. Such regeneration experiences stimulate accurate recall when they are designed to occur during or immediately after instruction (as in Design Principle #2).

Moving in a vertical pattern through Figure 3, the designer would focus on different life or landforms in relation to processes. In this design, sets of experiences would focus on concrete knowledge and move into abstract and teleological knowledge. The teacher-designer would scaffold experiences by moving from physical processes (tenet 6), through change (tenet 7) and into intangible concepts, such as God's purposes or teleological considerations (tenet 8), and finally, into abstract concepts, that is, consideration of the ultimate purpose and meaning of existence and explorations of the manifestations of the Creator's plan or logic in the universe (tenet 9).

When designing any of these sequences of experiences, the teacher-designer should map instruction using mental chronometry, the mental operations or steps of processing, as separate scenarios and teach the rules for solving the different kinds of problems as they are the focus of instruction (as in Design Principle #4). The specification of mental operations (cognitive processing) are required for designing computer-based scenarios, but they should also be specified for materials or programs designed for publication in other formats because each step of processing is a separate constructive cognitive operation with its own potentials for error.

Application to Generating Learning Strategy Structures

One of the most effective learning strategies available for generating cognitive experience is the inductive process or scientific method. The inductive process is the learning strategy that Jesus, the master teacher, used when he appeared to his disciples after his resurrection. In Luke 24: 36–53, we hear the physician Luke describing events through a scientist's eyes. The story demonstrates the three steps of the inductive reasoning process used by Luke as he sets forth proof of Jesus' resurrection. Here is Luke's story, presented with semantic cues and italics added to emphasize the steps of mind taken during the inductive or scientific process.

Step 1: Concept formation

Luke tells the story in terms of human senses as he lists sensory evidence (verbs) to support the concept that Jesus lives. Luke 24:66–43 says:

> Jesus himself *stood* among them and *said* to them, "Peace *be* with you." They *were startled* and *frightened*, *thinking* they *saw* a ghost. He *said* to them, "Why *are* you *troubled* and why *do doubts rise* in your minds? *Look* at my hands and my feet. It *is* I myself! *Touch* me and *see*; a ghost does not have flesh and bones, as you *see* I have." (NIV, 2003, pp. 1694–1695),

Step 2: Interpretation of data

For his disciples, Jesus identifies critical relationships between current events and the Scriptures. He shows the disciples how to understand the Scriptures by opening their minds to the relevance of current events, and then he makes an inference for the disciples as to their role as ear- and eyewitnesses. He also infers that if they stay in the city as directed, they will be clothed with power from on high. In Luke 24:44–49, Luke writes:

> He *said* to them, "This is what I *told* you while I was still with you: Everything *must be fulfilled* that *is written* about me in the Law of Moses, the Prophets and the Psalms." Then he *opened* their minds so they could *understand* the Scriptures. He *told* them, "This is what *is written*: The Christ *will suffer* and *rise* from the dead on the third day, and repentance and forgiveness of sins *will be preached* in his name to all nations, beginning in Jerusalem. You *are* witnesses of these things. I am going to send you what my Father has promised; but stay in the city until you *have been clothed* with power from on high." (NIV, 2003, pp. 1694–1695)

Step 3: Application

In Luke 24:50–53, Luke describes the consequences of the disciples' experiences, that is, the results of the seeing, hearing, understanding and experiencing Jesus after his death and resurrection. The passage concludes with a description of the consequences of their experiences, the joy and the ongoing praise it produced. Luke writes:

> I am going to *send* you what my Father *has promised*; but *stay* in the city until you *have been clothed* with power from on high." When he *had led* them out to the vicinity of Bethany, he *lifted up* his hands and *blessed* them. While *he was blessing* them, he *left* them and was *taken up* into heaven. They *worshiped* him and *returned* to Jerusalem with great joy. And they *stayed* continually at the temple, *praising* God. (NIV, 2003, pp. 1694–1695)

By engaging the disciples in inductive reasoning processes, Jesus cognitively changed them. First, he gave them sensory (brain changing) evidence. Second, he helped them establish new relationships between past and present knowledge and expanded their role by calling them witnesses. Third, he produced in them a new pattern of understanding so that they responded by worshiping him and praising God, that is, their minds were reshaped, renewed by the knowledge given to them.

Figure 5 presents a graphic organizer reviewing the steps of the inductive process for this paper. Notice that the graphic for the inductive process has the visual shape or pattern of an hourglass (see Figure 5).

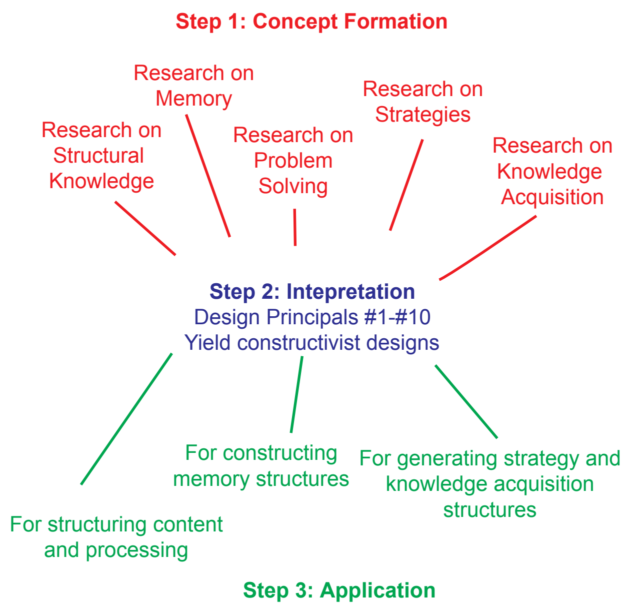

Figure 5. Graphic organizer for the inductive process.

Figure 5 presents a graphic organizer for the *inductive or scientific process*. This is the natural cognitive process by which learners take in sensory experience, restructure their understanding of the world, and apply new knowledge to memory as they develop increasingly complex knowledge structures. The process represents three major steps of generative cognitive activity that the learner engages in while coming to know the world inductively. This pattern for learning is fundamental to scientific exploration and to constructing a Christian worldview.

Principle #4 and Principle #5 stress the importance of teaching learners how to solve different types of problems and including instruction in the steps of process or mental operations for the different kinds of problems that are the focus of instruction. In teaching the Institute for Creation Research tenets of scientific creationism using the inductive model, the teacher-designer should not only engage learners in the steps of the model but also point the steps of processing required to achieve inductive thinking.

When training teachers to think and teach inductively, the teacher educator should post the steps of the inductive process (Step 1: Concept Formation, Step 2: Interpretation, Step 3: Application) to cue shifts of mind, and then explicitly move teachers through the steps by referring to the verbal cues. By modeling mapping and verbal cueing processes, the teacher educator can build structural knowledge and build cognitive teaching structures that teachers can employ to teach inductive thinking to learners of all ages.

In planning materials or programs, the teacher-designer must make many decisions regarding content and knowledge interrelationships. One of the most important decisions is the selection of the generative processes that learners will engage in during instructional experiences. Learning processing experiences must be appropriate to the content and to the learner's cognitive level of experience with learning strategies. For teaching the Institute for Creation Research tenets of scientific creationism, for example, an appropriate targeted processing pattern for all levels of abstraction would be scientific reasoning or the *inductive process*. By providing experiences that step learners through the tenets using the inductive process, the teacher-designer can help learners construct understanding of created forms and created processes in the real world. As a consequence of using this instructional framework, the teacher-designer can expect that learners' structural knowledge will reflect the content presented in the Institute for Creation Research tenets of scientific creationism and also include knowledge of the inductive process (as in Design Principle #1).

When planning content and/or processing patterns designed to generate structural knowledge, the teacher-designer can map the structure of knowledge for the field of study. *Graphic representations* can be used to illustrate the processing framework for different content areas and to help teachers and learners visually map relationships between content or experiences in an area of study. These graphics may take the form of a scale or a continuum, a chain of events, a cycle, an interaction outline, a comparison matrix, a problem/solution outline, or an inductive process hourglass (as in Figure 5).

To increase accuracy in memory for steps of a process, teacher-designers can provide learners of all ages with maps and verbal cues for the specific steps of process and steps of mind required for building specific processing structures and patterns. For teacher-designers of computer-based systems who must engage in requirements analysis, the processes and steps of mind identified by Joyce Weil (1986) represent scenarios (functional/cognitive behaviors) for computer-based instructional systems.

Steps of process also are important for assessment design. By designing assessments to focus on targeted content and steps of process during and after instruction, teacher-designers can use mapping tools to obtain accurate reports (assessments) from memory and measure progress toward achieving content and process learning goals (as in Design Principle #2). For instruction designed to improve mental processing during problem solving, the teacher-designer should map, as the content for instruction, the heuristics and strategy subroutines or steps required for problem solution, and the metacognitive strategies that can help with problem solving (as in Design Principle #5).

On these maps, the teacher-designer should note that time should be allowed for construction of strategies or new conceptual frameworks, for teaching simple verbal commands or rules for using problem solving strategies (that is, metacognitive strategies). In addition, the map should include problem-solving experiences in different contexts (that is, to promote transfer of structural knowledge) for each new strategy or conceptual framework (as in Design Principle #6).

Maps for instructional experiences provided to teachers should include notations on where specific learning strategies are included in the curriculum. For example, a map might note where opportunities for learners to look for patterns of errors in their productions or where learners would self-assess their progress or achievement of specific learning goals. These instructional experiences should be designed to help learners analyze their own writing, correct patterns, and eliminate errors in their productions and/or provide remedial experiences designed to help learners restructure errors in targeted patterns, concepts or relationships (as in Design Principle #7).

Application to Knowledge Acquisition Patterns

In mapping curriculum, it is important that teachers-designers use knowledge of learning models to plan instructional sequences that match needs of users. By selecting learning strategies to build structural knowledge (of learning strategies), the teacher-designer can move learners from dependence to independence as learners (as in Design Principle #8).

Content maps, such as *frames and slots* and *semantic maps* help the teacher-designer define content, explore relationships, and organize printed text and assessments. Learners also benefit from access to graphics that depict interrelationships using *semantic maps, concept maps*, *causal interaction maps*, or *graphic organizers (visual) or structured* *overviews (text).* Having maps available during learning experiences and teaching learners how to use them for organizing essays or recalling information for assessments can help learners organize new information within their knowledge structures for accurate recall (as in Design Principle #9).

Assessments can be mapped with generative knowledge acquisition experiences and can be designed to gather quality information about learners' thinking or knowledge structures. Teacher-designers can use a variety of assessment formats, including multiple-choice tests, constructed-response tests, direct classroom observation, individual interviews with students, journals that record thinking processes (knowledge structures), and other products and performances (as in Design Principle #10). By mapping assessment plans and testing formats used for measuring progress in content and process knowledge goals and by using a *causal interaction map* for pre-instruction and post-instruction assessments, the teacher-designer can set the stage for statistical analysis of changes in knowledge structures in teachers and/or learners who engage in the instructional experiences designed for teaching Institute for Creation Research tenet content (as in Figures 1 and 2) and interrelationships (as in Figure 3) and knowledge of inductive processes (as in Figure 5). Assessments then can be used formatively to improve instruction.

Conclusion

This paper demonstrates how mapping techniques can be used to direct information and object structure flow in designing materials and programs. There are advantages to using mapping techniques in designing materials and programs in different formats.

First, using mapping techniques, gives the teacher-designer the opportunity to explore relationships between concepts that might not be obvious in a listing of concepts. The list of Institute for Creation Research tenets of scientific creationism that appear in the Appendix, for example, does not depict the causal relationship between Tenet 1 and Tenets 2–9 (Figure 1). But this causal relationship is essential to understanding the creationist worldview. His dualistic nature causes mankind to claim his independence from God rather than claiming a causal relationship to God as his Creator. By mapping tenet content and exploring interactions between tenets, the teacher-designer has the opportunity to see the causal relationship between the creator and mankind as important content. In this example, the teacher-designer's use of mapping prevents an important error of omission in content.

Second, by mapping the steps of process, the teacher-designer can recognize the cognitive requirements and complexity of processing required for learning strategies and/or problem solving heuristics involved in the design. Through mapping, the teacher-designer can review the steps of process (scenarios) in the design and can ensure that all steps are included in the plan.

Third, by mapping concepts and steps of process, the teacher-designer can identify points during instruction where assessment can be used to test for error or misunderstanding. This mapping is of special value in designing criterion-referenced assessments. Assessment results collected during program use can be used for program evaluation. They can be used for formative evaluation and program redesign; and they can be used for summative evaluation and assessment of program value (relative to building knowledge that accurately mirrors the educational environment).

Fourth, mapping can be used as a market analysis tool by teacher-designers interested in finding voids or needs in an educational environment. This use of mapping can help define specific needs for materials, programs, or public museum displays for users at different knowledge levels. In this use of mapping, published programs and displays are reviewed and content is mapped as a scope and sequence for different subject areas or for different users. For example, materials designed to advance the Institute for Creation Research concepts of creation are sorted into the slots in a matrix for physical creation (as in Figure 2). Next, content and knowledge level are noted on entries. The map is reviewed, and slots and levels with few or no entries represent possible needs in the map of the educational environment.

If neural systems are active generative systems and there is a causal link between the structure of the environment and the structure of memory, as research indicates, then by organizing instructional content to consistently reflect the knowledge structure represented by the tenets of the Institute for Creation Research tenets of scientific creationism, especially the causal relationships, the teacher-designer can help the learner construct mental knowledge structures that mirror the Institute for Creation Research tenets of scientific creationism. Conversely, if the content of the specific knowledge structures (Institute for Creation Research tenets) is not present in the educational environment, then the Institute for Creation Research worldview is not mirrored in memory.

If the goal of the Institute for Creation Research is to help learners construct the worldview expressed in the Institute for Creation Research tenets of scientific creationism and teacher-designers understand the role that the learning environment plays in the construction of structural knowledge (worldview), then mapping the structural knowledge of scientific creationism for all the Institute for Creation Research tenets of scientific creationism and visually depicting relationships can help teacher-designers direct information and object structure design and plan textbooks and educational materials so that all the Institute for Creation Research tenets of scientific creationism are taught and mirrored in the minds of learners. But other techniques discussed in the research reviewed here also can inform design in a variety of contexts. They also should be used where appropriate. These include: mental chronometry and heuristics for problem solving (Swanson, O'Connor & Cooney, 1990), think aloud protocols (Robertson, 1990; Swanson, 1993; Langer & Applebee, 1987), strategy construction and syntax (Siegler & Jenkins, 1989; Joyce & Weil, 1986), self talk (Gagné, 1985), patterns of error (Shaughnessy, 1977), controlled composition (Gorrell, 1982), visual rhetoric (Helmers, 2004), and methods for representing structural knowledge through tests and assessments (Norris & Ennis, 1989; Jonassen, Beissner, & Yacci, 1993; Mislevy, Steinberg, & Almond, 2002).

References

Anderson, J.R., & Schooler, L.J. (1990) Reflections of the environment in memory. In D.H. Jonassen, K. Beissner, & M. Yacci (1993). S*tructural knowledge, techniques for representing, conveying, and acquiring structural knowledge* (p. 9). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Blair, J.A. (2004). The rhetoric of visual arguments. In C.A. Hill, & M. Helmers, (Eds.), *Defining visual rhetorics* (pp. 41–61). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Gagné, R.M. (1985). *The conditions of learning and theory of instruction*. New York, New York: Holt, Rinehart & Winston.

Gorrell, D. (1982). *Copy/write, basic writing through controlled composition*. Boston, Massachusetts: Little, Brown and Company.

Helmers, M. (2004). Framing the fine arts through rhetoric. In C.A. Hill, & M. Helmers, (Eds.), *Defining visual rhetorics* (pp. 63–86). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Hill, C.A., & Helmers, M. (Eds.) (2004). *Defining visual rhetorics*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Institute for Creation Research (2007). *Institute for Creation Research tenets of scientific creationism*. Santee, California: Retrieved 2006 from http://www.icr.org, click on Research, click on ICR Tenets.

Jonassen, D.H., Beissner, K., & Yacci, M. (1993). *Structural knowledge, techniques for representing, conveying, and qcquiring structural knowledge*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Jones, B.F., Pierce, J., & Hunter, B. (1989). Teaching students to construct graphic representations. *Educational Leadershi*p, December 1988/January 1989. Alexandria, Virginia: ASCD.

Joyce, B., & Weil, M. (1986). *Models of teaching* (3rd ed.). Englewood Cliffs, New Jersey: Prentice-Hall.

Kolb, B., & Whishaw, I.Q. (1990). *Fundamental of human neuropsychology*. New York, New York: W.H. Freeman & Co.

Langer, J.A., & Applebee, A.N. (1987). *How writing shapes thinking*. Urbana, Illinois: National Council of Teachers of English.

Love, T. (1993). *Object lessons*. New York, New York: SIG Books.

Mandler, J. (1983). Stories: The function of structure. Paper presented at the annual convention of the American Psychological Association, Anaheim, California, August 26–30, 1983. Referenced in D.H. Jonassen, K. Beissner, & M. Yacci (1993). S*tructural knowledge, techniques for representing, conveying, and acquiring structural knowledge* (pp. 8–9). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Mayer, R.E. (1992). *Thinking, problem solving, cognition* (2nd ed.). New York, New York: W.H. Freeman & Co.

Meyer, B.J.F. (1985). Signaling the structure of text. In D.H. Jonassen (Ed.), *The technology of text* (Vol. 2). Englewood Cliffs, New Jersey: Educational Technology Publications. Referenced in D.H. Jonassen, K. Beissner, & M. Yacci (1993). S*tructural knowledge, techniques for representing, conveying, and acquiring structural knowledge* (p. 16). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Mislevy, R.J., Steinberg, L.S., & Almond, R.G. (2002). On the roles of task model variables in assessment design (chap. 4). In S.H. Irvine, & P.C. Kyllonen (Eds.), *Item generation for test development*. Hillsdale, New Jersey: Lawrence Erlbaum Associates.

NIV (2003). *Spirit of the reformation study Bible, new international version*. Grand Rapids, Michigan: Zondervan.

Norris, S.P., & Ennis, R.H. (1989). *Evaluating critical thinking*. Pacific Grove, California: Critical Thinking Press & Software (Critical Thinking Company).

Robertson, W.C. (1990). Detection of cognitive structure with protocol data: Predicting performance on physics transfer problems. *Cognivite Science, 14*, 253–280. Referenced in D.H. Jonassen, K. Beissner, & M. Yacci (1993). S*tructural knowledge, techniques for representing, conveying, and acquiring structural knowledge* (p. 10). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Seidewitz, E., & Stark, M. (1995). *Reliable object-oriented software, applying analysis & design*. New York, New York: SIG Books.

Shavelson, R.J. (1972). Some aspects of the correspondence between content structrue and cognitive structure in physics instruction. *Journal of Educational Psychology, 63*, 225–234.

Shavelson, R.J. (1974). Methods for examining representations of subject matter structure in students' memory. *Journal of Research in Science Teaching, 11*, 231–249. In D.H. Jonassen, K. Beissner, & M. Yacci (1993). *Structural knowledge, techniques for representing, conveying, and acquiring structural knowledge* (p. 9). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Shavelson, R.J. (1988). *Statistical reasoning for the behavioral sciences*, (2nd ed., pp. 164–165). Needham Heights, Massachusetts: Allyn Bacon.

Shaughnessy, M.P. (1977). *Errors and expectations, a guide for the teacher of basic writing.* New York: Oxford University Press.

Siegler, R.S., & Jenkins, E. (1989). *How children discover new strategies.* Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Swanson, H.L. (1993). An information processing analysis of learning disabled children's problem solving. *American Educational Research Journal, 30*(4), 861–893.

Swanson, H.L., O'Connor, J.E., & Cooney, J.B. (1990). An information processing analysis of expert and novice teachers' problem solving. *American Educational Research Journal, 27*(3), 533–556.

Swartz, R.J., & Perkins, D.N. (1990). *Teaching thinking: Issues & approaches; AERA research in teaching and learning* (Vol. 3). Pacific Grove, California: Critical Thinking Press & Software (Critical Thinking Company).

Wenger, D.A. (1993). Restructuring schools through the teaching of thinking skills: A summary of findings from Best Friend Test, Survival Test, and Thoughts About Parents Test, studies of critical thinking. Carroll College, Graduate Program in Education, Waukesha, Wisconsin. Unpublished report.

Wittrock, M.C. (1990). *Students' thought processes; teachers' thought processes.* New York, New York: MacMillan Publishing Company & American Education Research Association.

Wittrock, M.C. (1992). Generative learning processes of the brain. *Educational Psychologist, 27*(4), 531–541.

Appendix

Institute for Creation Research Tenets of Scientific Creationism

Tenet 1: The physical universe of space, time, matter, and energy has not always existed, but was supernaturally created by a transcendent personal Creator who alone has existed from eternity. (Mapped as: creator)

Tenet 2: The phenomenon of biological life did not develop by natural processes from inanimate systems but was specially and supernaturally created by the Creator. Each of the major kinds of plants did not evolve from some other kind of organism. Changes in basic kinds since their first creation are limited to "horizontal" changes (variation) within the kinds, or "downward" changes (for example, harmful mutations, extinctions). (Mapped as: plants)

Tenet 3: Each of the major kinds of animals did not evolve from some other kind of organism. Changes in basic kinds since their first creation are limited to "horizontal" changes (variation) within the kinds, or "downward" changes (for example, harmful mutations, extinctions). (Mapped as: animals)

Tenet 4: The first human beings did not evolve from an animal ancestry, but were specially created in fully human form from the start. Furthermore, the "spiritual" nature of man (self-image, moral consciousness, abstract reasoning, language, will, religious nature, etc.) is itself a supernaturally created entity distinct from mere biological life. (Mapped as: humans)

Tenet 5: The record of earth history, as preserved in the earth's crust, especially in the rocks and fossil deposits, is primarily a record of catastrophic intensities of natural processes, operating largely within uniform natural laws, rather than one of gradualism and relatively uniform process rates. There are many scientific evidences for a relatively recent creation of the earth and the universe, in addition to strong scientific evidences that most of the earth's fossiliferous sedimentary rocks were formed in an even more recent global cataclysm. (Mapped as: landforms)

Tenet 6: Processes today operate primarily within fixed natural laws and relatively uniform process rates but since they were themselves originally created and are daily maintained by their Creator, there is always the possibility of miraculous intervention in these laws or processes by their Creator. Evidence for such intervention should be scrutinized critically, however, because there must be clear and adequate reason for any such action on the part of the Creator. (Mapped as: processes)

Tenet 7: The universe and life have somehow been impaired since the completion of creation, so that imperfections in structure, disease, aging, extinctions, and other such phenomena are the result of "negative" changes in properties and processes occurring in an originally-perfect created order. (Mapped as: change)

Tenet 8: Since the universe and its primary components were created perfect for their purposes in the beginning by a competent and volitional Creator and since the Creator does remain active in this now-decaying creation, there do exist ultimate purposes and meanings in the universe. Teleological considerations, therefore, are appropriate in scientific studies whenever they are consistent with the actual data of observation; and it is reasonable to assume that the creation presently awaits the consummation of the Creator's purpose. (Mapped as: purpose)

Tenet 9: Although people are finite and scientific data concerning origins are always circumstantial and incomplete, the human mind (if open to the possibility of creation) is able to explore the manifestations of that Creator rationally and scientifically, and to reach an intelligent decision regarding one's place in the Creator's plan. (Mapped as: logic)

* NOTE: For this discussion, plants and animals are separated into two tenets here but appear as one tenet in the ICR list of tenets. Names appearing in parentheses were added by the author.