First Principles of Instruction

☐ M. David Merrill

For the past several years the author has been reviewing instructional design theories in an attempt to identify prescriptive principles that are common to the various theories. This paper is a preliminary report of the principles that have been identified by this search. Five first principles are elaborated: (a) Learning is promoted when learners are engaged in solving real-world problems. (b) Learning is promoted when existing knowledge is activated as a foundation for new knowledge. (c) Learning is promoted when new knowledge is demonstrated to the learner. (d) Learning is promoted when new knowledge is applied by the learner. (e) Learning is promoted when new knowledge is integrated into the learner's world.

Representative instructional design theories are briefly examined to illustrate how they include these principles. These include: Star Legacy by the Vanderbilt Learning Technology Center, 4-Mat by McCarthy, instructional episodes by Andre, multiple approaches to understanding by Gardner, collaborative problem solving by Nelson, constructivist learning environments by Jonassen, and learning by doing by Schank.

It is concluded that, although they use a wide variety of terms, these theories and models do include fundamentally similar principles.

☐ Recent years have seen a proliferation of instructional design theories and models. Tennyson, Schott, See, and Dijkstra (1997) and Reigeluth (1999) summarize a number of these different positions. Instructional design theory, as represented in Reigeluth, varies from basic descriptive laws about learning to broad curriculum programs that concentrate on what is taught rather than on how to teach. Are all of these design theories and models merely alternative ways to approach design? Do all of these design theories and models have equal value? Do these design theories and models have fundamental underlying principles in common? If so what are these underlying first principles? The purpose of this paper is to identify and articulate the prescriptive design principles on which these various design theories and models are in essential agreement.

Reigeluth (1999) distinguishes two major kinds of instructional methods: basic methods and variable methods. This paper identifies what Reigeluth calls basic methods but which I prefer to call first principles of instruction. This paper refers to variable methods as programs and practices. A *principle* (basic method) is a relationship that is always true under appropriate conditions regardless of program or practice (variable method). A *practice* is a specific instructional activity. A *program* is an approach consisting of a set of prescribed practices. Practices always implement or fail to implement underlying principles whether these principles are specified or not. A given instructional approach may only emphasize the implementation of one or more of these instructional principles. The same principles can be implemented by a wide variety of programs and practices. A given

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theory may specify both principles and practices for implementing these principles. For some examples in Reigeluth (1999) a program is specified but the underlying first principles are not specified. Parsimony would dictate that there should be only a few first principles of instruction that can support a wide variety of instructional programs and practices (design theories, models, and methods).

What are the properties of first principles of instruction? First, learning from a given program will be promoted in direct proportion to its implementation of first principles. Second, first principles of instruction can be implemented in any delivery system or using any instructional architecture. Third, first principles of instruction are design oriented or prescriptive rather than learning oriented or descriptive. They relate to creating learning environments and products rather than describing how learners acquire knowledge and skill from these environments or products.

In this paper, I have identified the principles that are included in a variety of design theories and models. There is no attempt in this paper to identify the empirical support for these principles. I assume, perhaps without sufficient justification, that if a principle is included in several instructional design theories, the principle has been found either through experience or empirical research to be valid. My associates and I are involved in a review effort to identify empirical research that supports or fails to support these design principles. The present report merely identifies the principles that have been identified by a variety of theorists and model builders.

The premise of this paper is that there is a set of principles that can be found in most instructional design theories and models and even though the terms used to state these principles might differ between theorists, the authors of these theories would agree that these principles are necessary for effective and efficient instruction. This premise also assumes that these design principles apply regardless of the instructional program or practices prescribed by a given theory or model. If this premise is true, there will be a decrement in learning and performance when a given instructional program or practice violates or fails to implement one or more of these first principles. Obviously, the support for this hypothesis can only come from evaluation studies for a given instructional product or research studies comparing the use and misuse of these principles.

The theories cited in this paper are illustrative of our approach rather than exhaustive. Not all of the principles stated in this paper are included in the theories that are very briefly described. The vocabulary used to describe these theories and their implementation details varies significantly. Each of the theories and models reviewed here tends to emphasize different principles.

This paper will provide a concise statement of these first principles of instruction and then review selected theories to see how these principles are incorporated by each of these theories. As each theory is reviewed, there will be an attempt to translate the vocabulary of the theory to the vocabulary of the first principles as stated.

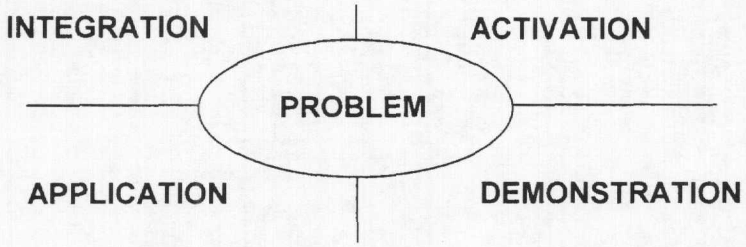
INSTRUCTIONAL PHASES

Many current instructional models suggest that the most effective learning products or environments are those that are problem-centered and involve the student in four distinct phases of learning: (a) activation of prior experience, (b) demonstration of skills, (c) application of skills, and (d) integration of these skills into real-world activities. Figure 1 illustrates these four phases. Much instructional practice concentrates primarily on the demonstration phase and ignores the other phases in this cycle of learning.

Most of the theories reviewed in this paper stress problem-centered instruction and include some (if not all) of these four phases of effective instruction. Figure 1 provides a conceptual framework for stating and relating the first principles of instruction. The first principle relates to problem-centered instruction. Four more principles are stated for each of the four phases for effective instruction. These five first principles stated in their most concise form are as follows:

1. Learning is promoted when learners are engaged in solving real-world problems.
2. Learning is promoted when existing

Figure 1 ☐ Phases for Effective Instruction



knowledge is activated as a foundation for new knowledge.[1]

3. Learning is promoted when new knowledge is demonstrated to the learner.
4. Learning is promoted when new knowledge is applied by the learner.
5. Learning is promoted when new knowledge is integrated into the learner's world.

FIRST PRINCIPLES OF INSTRUCTION

In the following paragraphs, I elaborate the five prescriptive design principles for problem-centered instruction and for each of the four instructional phases. First, I state each principle and its corollaries including a short descriptor for each principle or corollary. After this concise statement, I elaborate and explain the principle and its corollaries in more detail citing some representative theorists or investigators who have suggested the principle.

Principle 1—Problem-centered: Learning is promoted when learners are engaged in solving real-world problems.

- *Corollary—Show task:* Learning is promoted when learners are shown the task that they will be able to do or the problem they will be able to solve as a result of completing a module or course.
- *Corollary—Task level:* Learning is promoted when learners are engaged at the problem or task level, not just the operation or action level.
- *Corollary—Problem progression:* Learning is promoted when learners solve a progression of problems that are explicitly compared to one another.

Problem-centered

Much of the current work in cognitive psychology has shown that students learn better when engaged in solving problems (Mayer, 1992a). Problem-centered learning is well represented by a number of recent instructional models including: Collins, Brown and Newman (1989), *Cognitive Apprenticeship;* Schank, Berman, and Macperson (1999), *Goal Based Scenarios;* Jonassen (1999), *Constructivist Learning Environments;* Savery and Duffey (1995), *Problem-Based Learning;* Clark and Blake (1997), *Novel Problem Solving;* and van Merriënboer (1997), *Whole Task Practice in 4C/ID Model.*

The definition of a *problem* varies among theorists. For some, a problem is engaging in some form of simulation of a device or situation. For others, it merely means being involved in some form of real world task. I use the word *problem* to include a wide range of activities, with the most critical characteristics being that the activity is some whole task rather than only components of a task and that the task is representative of those the learner will encounter in the world following instruction. Problem-centered instruction is contrasted with topic-centered instruction where components of the task are taught in isolation (e.g., "You won't understand this now but later it will really be important to you") before introducing the real world task to the students.

1. I used the word *knowledge* in its broadest connotation to include both knowledge and skill, and to represent the knowledge and skill to be taught as well as the knowledge and skill acquired by the learner.

Show task

It has become common practice to state learning objectives at the beginning of module or lesson material. These objectives are usually some form of: "The learner will be able to . . . ." Objectives of this form are abstract and often only understood following the instruction. Most theorists suggest that a specific demonstration of the particular whole task similar to those the learners will be able to do following instruction provides a better orientation to the instructional material to follow than a list of abstract objective statements. Van Merriénboer (1997) recommended that the first problem in a sequence should be a worked example that shows students the type of whole task that they will learn to complete.

Task level

Much available instruction teaches commands or individual actions and assumes that the learner will be able to put these individual components together to do real world tasks. Too much traditional instruction is topic based, teaching all the prerequisites before introducing the real world whole task or problem. Learning to complete a whole task involves four levels of instruction: (a) the problem, (b) the tasks required to solve the problem, (c) the operations that comprise the tasks, and (d) the actions that comprise the operations. Effective instruction should engage students in all four levels of performance: the problem level, the task-level, the operation-level, and the action-level. Schank et al. (1999) stressed that one shortcoming of traditional instruction is the emphasis on decontextualized skills. Jonassen (1999) stressed that learners will assume ownership only if the problems to be solved are interesting, relevant and engaging. Other theorists have stressed that effective learning requires engaging the learners in authentic problems (Savery & Duffy, 1995; Nelson, 1999).

Problem progression

Some of the problems or whole tasks that learners must complete are very complex. Most theorists would agree that solving a single problem or receiving little or no guidance (sink-or-swim) is not effective. To master a complex problem students must first start with a less complex problem. When the first problem is mastered, students are then given a more complex problem. Through a progression of increasingly complex problems, the students' skills gradually improve until they are able to solve complex problems. Problem progression is advocated by *Elaboration Theory* (Reigeluth, 1999), *4C/ID Model* (van Merriënboer, 1997), *work model progression* (Gibbons, Bunderson, Olsen, & Robertson, 1995), *scaffolding* (Collins, et al., 1989), and *understanding-performances* (Perkins & Unger, 1999).

Activation Phase

Principle 2—Activation: Learning is promoted when relevant previous experience is activated.

- *Corollary—Previous experience:* Learning is promoted when learners are directed to recall, relate, describe, or apply knowledge from relevant past experience that can be used as a foundation for the new knowledge.
- *Corollary—New experience:* Learning is promoted when learners are provided relevant experience that can be used as a foundation for the new knowledge.
- *Corollary—Structure:* Learning is promoted when learners are provided or encouraged to recall a structure that can be used to organize the new knowledge.

Activation

It has long been a tenet of education to start where the child is. It is therefore surprising that many instructional products jump immediately into the new material without laying a sufficient foundation for the students. If students have had relevant experience, then the first phase of learning is to be sure that this relevant information is activated ready for use as a foundation for the new knowledge. If students have not had sufficient relevant experience, then the first phase of learning a new skill should be to provide three-dimensional experience that they can use as a foundation for the new knowledge. Too much instruction starts with abstract representations for which learners have insufficient foundation. This paper borrowed the term *activation* from Andre (1997) who provided one of the best recent discussions of this principle.

Previous experience

When learners think that they already know some of the material to be taught, then their existing experience can be activated by an appropriate opportunity to demonstrate what they already know. This activity can be used to help direct students to the yet-to-be-learned new material and thus result in more efficient instruction. Requiring students to complete the usual information-oriented pretest of the material to be taught when they don't feel that they know the material is frustrating and not productive in activating prior experience. A simple recall of information is seldom effective as an activating experience. Andre (1997) cited theory and research supporting schema activation and advance organizers.

Provide experience

Often the new learning may be foreign to the previous experience of the learner. When instruction jumps immediately to this new material the learner feels overwhelmed. Elementary school teachers understand this phenomenon and spend considerable time providing experiences upon which later learning can be built. As learners mature the educational system seems to feel that providing relevant experience prior to instruction is no longer necessary. Consequently students must resort to memorizing the material presented because they lack previous mental models based on experience that can be used to structure the new knowledge.

Structure

Activation is more than merely helping students recall previous experience or providing relevant experience. Activation also involves stimulating those mental models that can be modified or tuned to enable learners to incorporate the new knowledge into their existing knowledge. Andre (1997) cited theory and research showing that themes can serve as an organizing structure if they are relevant to the content being taught. There is a current emphasis on introducing motivational themes into instruction, for example, playing golf, flying a space ship, and so forth. When these themes are irrelevant to the content of the instruction, they activate inappropriate mental models and may actually interfere with, rather than promote instructional effectiveness. In an attempt to promote motivation, these themes may actually increase the cognitive load required to acquire the target knowledge. If learners have a mental model that can be used to organize the new knowledge, they should be encouraged to activate this mental model. However, if the mental model is insufficient to adequately organize the new knowledge, then learning is promoted if the instruction provides a structure that the learner can use to build the required organizational schema for the new knowledge. Andre (1997) discussed the role of advance organizers in providing structure for later learning. Mayer (1975) indicated that providing learners with a conceptual model can facilitate the acquisition of problem solving. Clark and Blake (1997) recommended presenting dynamic schema and analog models to promote far transfer.

Demonstration Phase

Principle 3—Demonstration (Show me): Learning is promoted when the instruction demonstrates what is to be learned rather than merely telling information about what is to be learned.

- *Corollary—Demonstration consistency:* Learning is promoted when the demonstration is consistent with the learning goal: (a) examples and nonexamples for concepts, (b) demonstrations for procedures, (c) visualizations for processes, and (d) modeling for behavior.
- *Corollary—Learner guidance:* Learning is promoted when learners are provided appropriate learner guidance including some of the following: (a) learners are directed to relevant information, (b) multiple representations are used for the demonstrations, or (c) multiple demonstrations are explicitly compared.

- *Corollary—Relevant media:* Learning is promoted when media play a relevant instructional role and multiple forms of media do not compete for the attention of the learner.

Demonstration (Show me)

Knowledge to be learned exists at two levels: (a) information and (b) portrayal. Information is general and inclusive and refers to many cases or situations. Portrayal is specific and limited and refers to a single case or a single situation. Presenting information is by far the most common form of instruction. Often instruction is merely information followed by a few remember-what-you-were-told questions. This tell-and-ask instruction by itself is seldom effective instruction. Instruction is far more effective when it also includes the portrayal level in that the information is demonstrated via specific situations or cases. Learners remember and can apply information far more readily when the information includes specific portrayals. Van Merrienboer (1997) identified a number of different problem formats. He indicated that showing a learner what to do via a worked-out example and modeling examples, which show the learner how to do the problem, are important first steps in an instructional sequence. Merrill (1994) cited research that shows that presenting examples is more effective than merely presenting information; presenting examples in addition to practice promotes better learning than practice alone.

Demonstration consistency

Gagné (1985) identified categories of learning and suggested that effective learning occurs when the conditions of learning were consistent with the desired category of learned performance. Merrill (1994) elaborated the categories of Gagné and prescribed primary and secondary presentation forms consistent with each outcome category. Merrill (1997) identified the knowledge structure, presentation, practice, and learner guidance that are consistent for each of these different kinds of learning outcomes. Dijkstra & van Merriënboer (1997) identified three classes of problems: (a) problems of categorization, (b) problems of design (plans and procedures), and (c) problems of interpretation (principles, models, and theories). Each of these different classes of problems require different knowledge structures (corresponding to the desired cognitive structure) and different constituent skills (concepts, activities, and processes) if learning is to be efficient and effective. Van Merriënboer (1997) has extended this work in the context of problem-centered instruction. These theorists agree that if demonstrations are inconsistent with the intended learning outcomes then learning will be ineffective. The consistency criterion should be applied first since if the presentation is inconsistent with the intended learning outcome then it doesn't matter if there is learner guidance or if the media is relevant.

Learner guidance

Clark & Blake (1997) indicated that problem solving (far transfer) is promoted when the structural features are carefully identified and explicitly mapped for the student. This explicate guidance focuses the learner's attention on relevant information in the task. Early in an instructional presentation this attention-focusing function facilitates knowledge acquisition. However, as the instruction progresses this information focusing role should be faded and students expected to attend to and focus their own attention on the relevant aspects of the information (Andre, 1997).

Another form of guidance is to provide learners with multiple representations of the ideas being taught and the demonstration being provided. Spiro and Jehng (1990), Schwartz, Lin, Brophy, and Bransford (1999), and Clark and Blake (1997) all stressed the importance of alternative points of view, especially for ill-defined domains and nonrecurrent skills. Spiro, Feltovich, Jacobson and Coulson (1992), in cognitive flexibility theory, stressed the importance of coming at a given topic from multiple perspectives.

Gentner and Namy (1999) have demonstrated that merely presenting alternative representations is not sufficient. When learners are explicitly directed to compare different viewpoints they are forced to tune their mental models to provide a broader perspective.

Relevant media

Mayer (1992b, 2001) has demonstrated that gratuitous illustrations make little or no instructional contribution and are often ignored by learners or may actually interfere with efficient learning He has also demonstrated that some combinations of multimedia (e.g., text and a graphic) compete for attention and therefore increase the cognitive load for the student. Other combinations of media, such as audio and graphics, support one another and promote more effective learning.

Application Phase

Principle 4—Application (Let me): Learning is promoted when learners are required to use their new knowledge or skill to solve problems.

- *Corollary—Practice consistency:* Learning is promoted when the application (practice) and the posttest are consistent with the stated or implied objectives: (a) information-about practice—recall or recognize information, (b) parts-of practice—locate, and name or describe each part, (c) kinds-of practice—identify new examples of each kind, (d) how-to practice—do the procedure and (e) what-happens practice—predict a consequence of a process given conditions, or find faulted conditions given an unexpected consequence.
- *Corollary—Diminishing coaching:* Learning is promoted when learners are guided in their problem solving by appropriate feedback and coaching, including error detection and correction, and when this coaching is gradually withdrawn.
- *Corollary—Varied problems:* Learning is promoted when learners are required to solve a sequence of varied problems.

Application (Let me)

Merrill (1994) cited research demonstrating that adding practice to information and examples increases learning. Most instructional design theories advocate application of knowledge and skill as a necessary condition for effective learning. Gagné (1985) stated eliciting performance and providing feedback as necessary instructional events. Gardner (1999) and Perkins and Unger (1999) both emphasized the necessity of many opportunities for performance. All of the problem-based models (Clark & Blake, 1997; Jonassen, 1999; Nelson, 1999; Savery & Duffy, 1995; Schank et al., 1999; Schwartz et al., 1999; van Merriënboer, 1997) emphasized the importance of being involved in doing real-world tasks or problems. It is astounding that with this almost universal agreement on the importance of applying knowledge to real-world tasks, so much instruction merely includes a few multiple-choice questions that are labeled practice. Such remember-what-you-were-told questions do little to promote learning.

Practice consistency

Just as there are different components of knowledge, presentation, and learner guidance appropriate for different kinds of instructional goals, so there are different kinds of practice appropriate for different instructional goals. Engaging in practice that is inconsistent with the desired instructional goal will do little to improve performance. Gagné (1965, 1985) and Merrill (1994, 1997) identified appropriate practice for each of the kinds of knowledge and skill identified. Learning is promoted when the practice is consistent with the learning goal. The consistency criterion should be applied first. If the application is inconsistent with the intended goals of the instruction, then it will be ineffective and it won't matter whether or not there is appropriate coaching and feedback or a sequence of problems.

Diminishing coaching

One theory of effective instruction is scaffolding (Burton & Brown, 1979; Collins et al., 1989). The idea is that early in learning students need considerable support, but as the learning progresses this support is gradually taken away leaving the students eventually on their own. Scaffolding involves performing parts of the task that the students cannot perform and gradually reducing the amount of guidance and shifting the control to the student.

Feedback has long been recognized as the most important form of learner guidance. All theories advocate some form of feedback as a necessary condition for learning. Gagné (1985) included feedback as one of the events for instruction. Andre (1997) included feedback as one of his three phases of effective instruction. Numerous research studies have demonstrated the importance of feedback while investigating a number of variables about what type of feedback is most effective (Kulhavy, 1977; Kulhavy & Stock, 1989).

Making errors is a natural consequence of problem solving. Most learners learn from the errors they make, especially when they are shown how to recognize the error, how to recover from the error, and how to avoid the error in the future. Error diagnosis and correction is a fundamental principle of minimialism (van der Meij & Carroll, 1998).

Varied problems

Applying knowledge to a single problem is insufficient for learning a cognitive skill. Adequate practice must provide multiple opportunities for learners to use their new knowledge or skill for a variety of problems. Andre (1986) indicated the importance of providing learners with a range of examples. Merrill, Tennyson, and Posey (1992) indicated that a necessary condition for effective concept instruction was a range of divergent examples. Tennyson & Park (1980) and Tennyson & Cocchierella (1986) reviewed research demonstrating the value of a sequence of varied examples in concept instruction, and van Merrienboer (1997) stressed variability of practice.

Integration Phase

Principle 5—Integration: Learning is promoted when learners are encouraged to integrate (transfer) the new knowledge or skill into their everyday life.

- *Corollary—Watch me:* Learning is promoted when learners are given an opportunity to publicly demonstrate their new knowledge or skill.
- *Corollary—Reflection:* Learning is promoted when learners can reflect on, discuss, and defend their new knowledge or skill.
- *Corollary—Creation:* Learning is promoted when learners can create, invent, and explore new and personal ways to use their new knowledge or skill.

Integration

McCarthy (1996) suggested that the fourth phase of effective instruction is creating personal adaptations of the new knowledge and skill. The Vanderbilt group (Schwartz et al., 1999) included reflecting back on the experience as a step in their Star Legacy system. Current instruction literature has much to say about the importance of motivation. Often glitz, animation, multimedia, and games are justified as motivational elements of an instructional product. However, for the most part, these aspects have a temporary effect on motivation. The real motivation for learners is learning. Learners have integrated instruction into their lives when they are able to demonstrate improvement in skill, to defend their new knowledge, and to modify their new knowledge for use in their everyday lives.

Watch me

Whenever learners acquire new skills, their first desire is to show a close friend or associate their newly acquired ability. Learning is the most motivating of all activities when the learner can observe his or her own progress. One of the main attractions of computer games is the increasing skill level that is apparent to the player. Effective instruction must provide an opportunity for learners to demonstrate their newly acquired skills. This principle of going public with their newly acquired knowledge is emphasized in *Teaching for Understanding* (Gardner, 1999; Perkins & Unger, 1999) and for Vanderbilt's *Star Legacy* (Schwartz et al., 1999).

Reflection

Learners need the opportunity to reflect on, defend, and share what they have learned if it is to become part of their available repertoire. Nelson (1999) cites a number of problem-solving models that include *synthesize and reflect* as an important process activity for collaborative problem solving. Laurillard (1993) stressed the role of reflection in her *Conversational Framework* model of instruction. Boud, Keogh, and Walker (1985) presented a model for reflection in learning.

Creation

Modifying new knowledge to make it one's own is where a learner moves beyond the instructional environment and takes the new knowledge and skill into the world beyond. McCarthy (1996) stressed creating, revising, editing, synthesizing, and refocusing as important final phases of a learning experience.

AN ANALYSIS OF REPRESENTATIVE INSTRUCTIONAL THEORIES

This section briefly reviews several instructional theories. The theories described in this section all implement some of the first principles and their corollaries. Since the vocabulary is often different, this paper attempts to do some translation of theorist's terms to be consistent with the terms used in the above statement of the principles. I have sometimes quoted these authors to provide the reader with the vocabulary of the theorists so that the reader can see first hand how the statements have been interpreted as representative of the first principles outlined in this paper. This overview is representative only and does not present all of the principles specified by the theory, but only enough to give the reader a feel for the correspondence with the first principles stated. The reader is encouraged to examine these and other theories in detail to determine whether or not the theory reflects the first principles as stated.

Herbart (1776 - 1841)

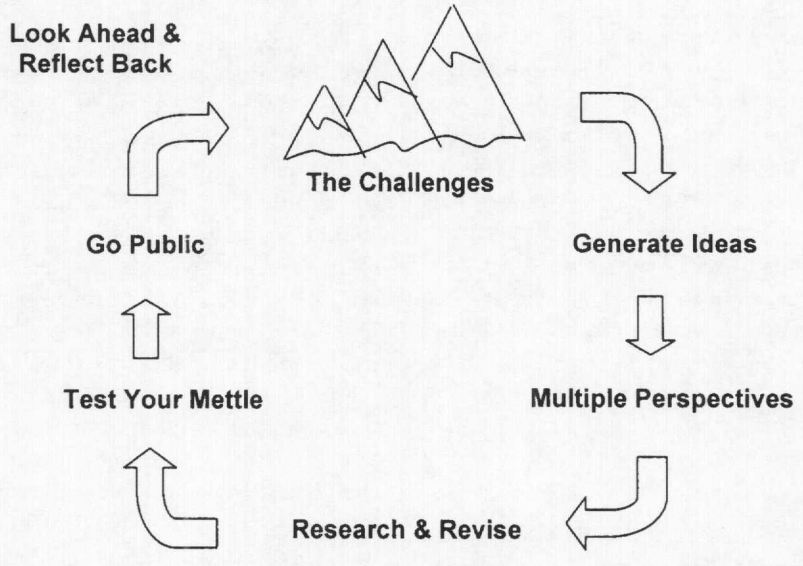
The first principles of instruction presented in this paper are not new. Johann Friedrich Herbart is often identified as the father of scientific pedagogy. He recommended that the teacher should first prepare the pupils to be ready for a new lesson. Further, he suggested that the pedagogy should associate the new lesson with ideas studied earlier. Both of the recommendations are consistent with the principle of activation. He also recommended that the pedagogy should use examples to illustrate the lesson's major points. Clearly, he also emphasized demonstration in addition to the presentation of information. Finally he recommended that the pedagogy should test pupils to ensure they have learned the new lesson. This is the principle of application (Hilgenheger, 1993).

Vanderbilt Learning Technology Center—Star Legacy

The Learning Technology Center at Vanderbilt (Schwartz et al., 1999) described Star Legacy, a software shell for instruction. The Vanderbilt approach is a good illustration of the phases of instruction and the five general principles that have been identified. They describe a learning cycle that, they believe, involves important, yet often implicit, components of effective instruction. They emphasize making the learning cycle explicit. Their learning cycle is illustrated in Figure 2.

Look ahead provides the learning context and learning goals. The *challenges* are problems to be solved. The Vanderbilt group (Schwartz et al., 1999) uses the metaphor of successively higher mountains to represent a progression of increasingly difficult problems. *Generate ideas* is an activation activity where learners interact with other learners to share experience and to share what they already know related to the challenges. *Multiple perspectives* is an opportunity for students to compare their view of the problem and possible solutions with the view of other students and, more importantly, with the view of experts. During multiple perspectives concepts, procedures and principles that the student

Figure 2 ☐ Learning Cycle of Star Legacy (Schwartz et al., 1999)



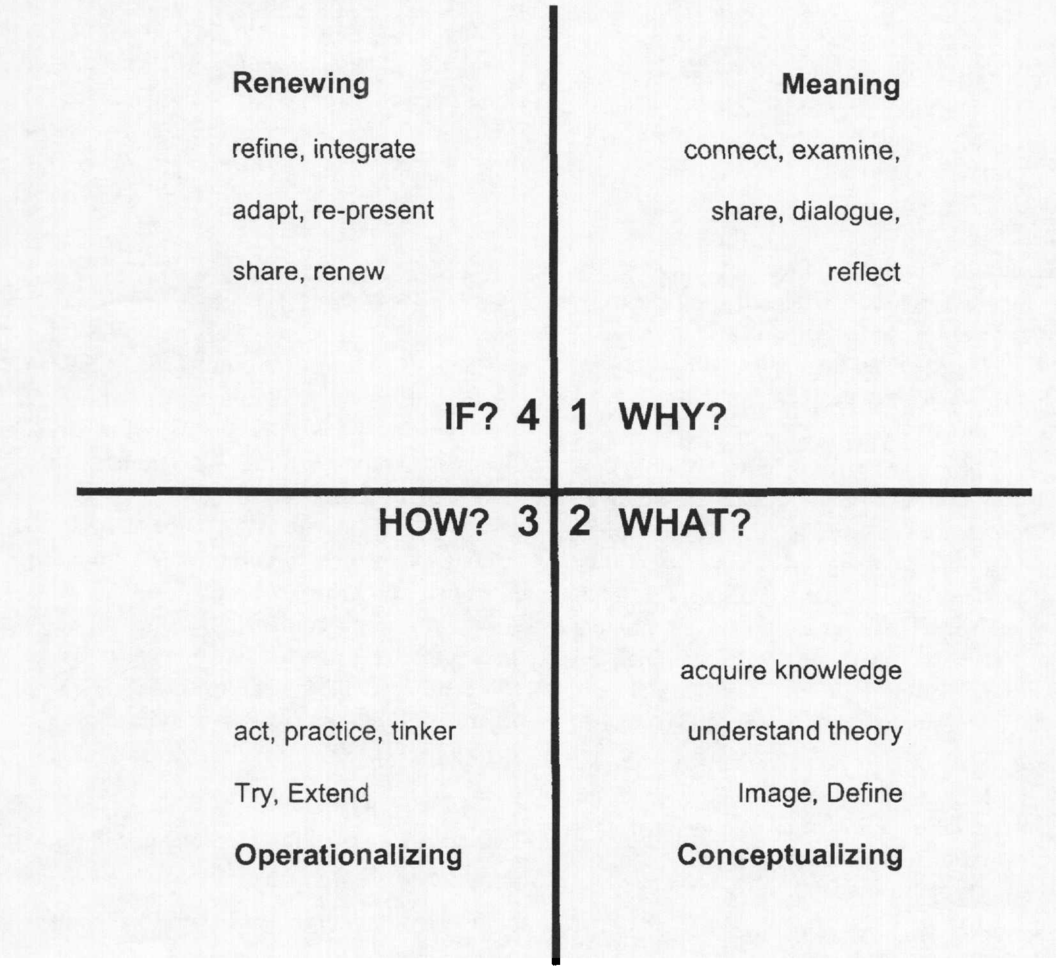
may need in order to solve the problem are demonstrated. *Research and revise* continues the demonstration phase and moves into the application phase; students gather numerous different ideas and try them out to see how they might solve the problem. *Check your mettle* is an opportunity for students to apply their ideas and receive feedback before they go public with their solutions. *Go public* is a chance for the students to demonstrate their solutions and to defend their ideas. This is an important component of the integration phase of instruction. *Reflect back* is an opportunity for the students to review their learning activities and is another important aspect of integration. Because the authors believe that the learning cycle should be made explicit, Star Legacy is one of the most explicit representations of the learning cycle that forms the structure for the first principles of instruction. This same cycle of learning is also found in other theories and models, but it is frequently more subtle and not as explicit as in Star Legacy.

McCarthy—4-MAT

McCarthy (1996) represented a model used by many teachers in K–12 education. McCarthy is seldom cited in the instructional technology literature. Her work is important to our consideration of first principles because she made the learning cycle explicit. McCarthy approached this idea from a consideration of student learning styles but concluded that, although learners may have preference for various approaches to learning, effective instruction requires them to be involved in the whole cycle of learning activities. Figure 3 illustrates some of the ideas that she emphasized in her 4-MAT approach.

McCarthy did not emphasize problem solving as much as did the Learning Technology Center. Her emphasis was on the various types of activities that might be appropriate for each of the learning phases and how these learning activities reflect learning preferences of various types of learners. Her Phase 1 serves the role of activation, in which the learners share what they know and try to find meaning related to the new material they will learn. 4-MAT Phase 1 is similar to Star Legacy's *generate ideas*, but emphasizes a more learner-centered approach, whereas the Vanderbilt group is more problem focused. 4-MAT Phase 2 is the demonstrate phase, where the learners acquire new knowledge and relate it to what they already know. McCarthy (1996) included subphases, the description of which is beyond the scope of this

Figure 3 ☐ McCarthy 4-MAT Cycle of Learning (McCarthy, 1996)



presentation, but which provide practices and theory for making the transition from one phase to the next. Phase 3 is clearly the application phase, where learners use what they know to do something, make something, or play with the ideas. This phase is also related to the Star Legacy *research and revise* and *test your mettle* components. McCarthy Phase 4 is where learners make the knowledge their own. This is the integration phase of first principles, and I borrowed McCarthy's term *integration* for this phase. The formulation of the learning cycle for first principles and the graphic representation of these phases were influenced by McCarthy's work. She provided perhaps the most explicit articulation of the cycle of learning and the phases required for effective instruction.

Andre—Instructional Episode

Andre's (1997) work was focused on the research supporting instruction rather than a theory per se. He described an instructional episode consisting of three major phases: (a) activation phase (from which first principles borrowed the term), (b) instructional phase, and (c) feedback phase. For Andre the instructional phase consisted of presentation, discovery and practice (the first principles demonstration and application phase). His feedback phase was only part of the first principles application phase as described above. Andre did not emphasize problem solving or integration following the practice-feedback phase. Andre described research findings that support a number of the corollaries stated above.

Gardner—Multiple Approaches to Understanding

Gardner's (1999) *performance approach to understanding* emphasized understanding content ("important questions and topics of the world" p. 73) rather than problem solving, but his approach did embrace each of the four phases of instruction as described in this paper. He stressed that understanding can only be observed when students engage in "performances that can be observed, critiqued, and improved" (p. 73). He organized his theory around phases he identified as *entry points, telling analogies,* and *approaching the core.*

Entry points are a form of activation. "One begins by finding a way to engage the students and to place them centrally within the topic. I have identified at least six discrete entry points, which can be roughly aligned with specific intelligences" (p. 81). He then described entry points from these six viewpoints: (a) narrational, (b) quantitative-numerical, (c) foundational-existential, (d) aesthetic, (e) hands-on, and (f) social.

Telling analogies forms a transition from activation to demonstration. "[C]ome up with instructive analogies drawn from material that is already understood, and that can convey important aspects of the less familiar topic" (p. 82).

Approaching the core includes some of the prescriptions for demonstration. "[P]ortray the topic in a number of ways . . . [use] multiple approaches [that] explicitly call upon a range of intelligences, skills, and interests" (p. 85).

He also stressed application. "[M]ultiple representations is one component of effective teaching; the complementary component entails the provision of many opportunities for performance, which can reveal to the student and to others the extent to which the material has been mastered" (p. 86). "Although it is easy to fall back on the tried-and-true—the short answer test, the essay question—there is no imperative to do so. Performances can be as varied as the different facets of the topic, and the diverse sets of skills of students" (p. 87). Gardner did emphasize entry points and multiple approaches to the topic consistent with different kinds of intelligences, however, in his paper, he did not explicitly identify practice consistency with these different intelligences.

Perhaps the primary emphasis of Gardner was on those prescriptions for integration that involve going public. "When students realize that they will have to apply knowledge and insights in public form, they assume a more active stance vis-à-vis material, seeking to exercise their 'muscles of performance' whenever possible" (p. 74).

Nelson—Collaborative Problem Solving

Nelson's (1999) theory emphasized problem solving and included all of the phases, but with more emphasis on application and less emphasis on demonstration. She attempted to provide "an integrated set of guidelines . . . to design and participate in authentic learning environments which invoke critical thinking, creativity, and complex problem solving while developing important social interaction skills" (p. 246). She provided an extensive list of guidelines, and the source for these guidelines, organized under nine process activities:

1. Build readiness.
2. Form and norm groups.
3. Determine a preliminary problem definition.
4. Define and assign roles.
5. Engage in an iterative collaborative problem-solving process.
6. Finalize the solution or project.
7. Synthesize and reflect.
8. Assess products and processes.
9. Provide closure. (Nelson, 1999, Table 11.2, p. 258)

Some of these activities are clearly related to collaboration and, as such, are not included in our set of first principles (see especially numbers 2, 4, and 9). I view collaboration as one way to implement first principles; thus the activity guidelines for collaboration provided by Nelson are viewed as implementation guidelines rather than first principles.

Nelson (1999) was clearly problem oriented as demonstrated by the following guideline: "Develop an authentic problem or project scenario to anchor instruction and learning activities" (p. 258).

She promoted activation via the following learning activities: "[a] Negotiate a common understanding of the problem, [b] Identify learning issues and goals, and [c] Brainstorm preliminary solutions or project plans" (Nelson, 1999, p. 258).

She provided guidelines for gathering information that may be required for the problem-solving process. I view these activities as part of application rather than demonstration per se: "[a] Identify sources of needed resources, [b] Gather preliminary information to validate the design plan, [c] Acquire needed information, resources, and expertise, and [d] Collaborate with instructor to acquire additional resources and skills needed" (Nelson, 1999, p. 258).

Application activities include: "[a] Select and develop initial design plan, [b] Refine and evolve the design plan, [c] Engage in solution or project development work, [d] Conduct formative evaluations of the solution or project, [e] Draft the preliminary final version of the solution or project, [f] Conduct the final evaluation or usability test of the solution or project, [g] Revise and complete the final version of the solution or project, and [h] Evaluate the products and artifacts created" (Nelson, 1999, p. 258).

Integration activities include: "[a] Identify learning gains, [b] Debrief experiences and feelings about the process, and [c] Reflect on group and individual learning processes" (Nelson, 1999, p. 258).

Jonassen—Constructivist Learning Environments (CLE)

Jonassen's (1999) approach emphasized problem solving and included all four phases of instruction. The primary emphasis of CLE is problem solving as reflected in the following statements: "The goal of the learner is to interpret and solve the problem or complete the project" (p. 217), ". . . the problem drives the learning" (p. 218), "Students learn domain content in order to solve the problem, rather than solving the problem as an application of learning" (p. 218), and ". . . you must provide interesting, relevant, and engaging problems to solve. . . . The problem should not be overly circumscribed. Rather, it should be ill defined or ill structured, so that some aspects of the problem are emergent and definable by the learners" (p. 219). Jonassen recommended problem progression: "Start the learners with the tasks they know how to perform and gradually add task difficulty until they are unable to perform alone" (p. 235).

Some attention was directed toward activation. "What novice learners lack most are experiences. . . . Related cases [demonstrations] can scaffold (or supplant) memory by providing representations of experiences that learners have not had" (Jonassen, 1999, p. 223).

Demonstration was stressed: "Carefully demonstrate each of the activities involved in a performance by a skilled (but not an expert) performer. . . . Modeling provides learners with an example of the desired performance. . . . Two types of modeling exist: . . . Behavioral modeling . . . demonstrates how to perform the activities identified. . . . Cognitive modeling articulates the reasoning . . . that learners should use while engaged in the activities" (Jonassen, 1999, p. 231). "A widely recognized method for modeling problem solving is worked examples" (p. 232).

Application was also stressed, with an emphasis on coaching and scaffolding. "[I]n order to learn, learners will attempt to perform like the model, first through crude imitation, advancing through articulating and habituating performance, to the creation of skilled, original performances. At each of these stages the learner will likely improve with coaching" (Jonassen, 1999, p. 232). "The most important role of the coach is to monitor, analyze, and regulate the learners' development of important skills" (p. 233). Jonassen ". . . suggests three separate approaches to scaffolding of learning: adjust the difficulty of the task to accommodate the learner, restructure the task to supplant a lack of prior knowledge, or provide alternative assessments" (p. 235).

The reflection aspect of integration was suggested as one role of coaching. "[A] good coach provokes learners to reflect on (monitor and analyze) their performance" (p. 233).

Van Merriënboer—Four Component Instructional Design Model (4C/ID)

Van Merriënboer (1997) provided perhaps the most comprehensive recent model of instructional design that is problem-centered and involves all of the phases of instruction identified in this paper. His model integrated more directive approaches to instruction with problem-based approaches all in the context of what is known about cognitive processing. The model described multiple approaches to analysis and how the products of these various analysis techniques lead to instructional designs that focus on whole task practice. This short summary is inadequate to illustrate the comprehensive nature of the 4C/ID model.

The model was clearly problem-based. "At the heart of this training strategy is whole-task practice, in which more and more complex versions of the whole complex cognitive skill are practiced. . . . In . . . the analysis phase . . . the skill is decomposed in a hierarchy of constituent skills; . . . classified as recurrent constituent skills, which require more-or-less consistent performance over problem situations, or nonrecurrent constituent skills, which require highly variable performance over situations" (van Merriënboer, 1997, p. 8). "While learners practice simple to complex versions of a whole task, instructional methods that promote just-in-time information presentation are used to support the recurrent aspects of the whole task while, at the same time, instructional methods that promote elaboration are used to support the nonrecurrent aspects of the task" (p. 10).

Van Merriënboer's (1997) model did not explicitly address the issue of activation. However, his detailed attention to analysis and the various kinds of knowledge that comprise an instructional sequence certainly addressed some of the concerns of activation.

Demonstration was addressed at several levels. The first problems in a sequence should be worked-out examples of how to perform the task. As the student progresses through the sequence of problems other information is presented or demonstrated. These include part-task practice for development of "situation specific, automated rules . . ." (van Merriënboer, 1997, p. 12). For just-in-time information, "Demonstration is usually needed to illustrate the application of rules or procedures and to exemplify concepts, principles, or plans that are prerequisite to a correct application of those rules or procedures [in solving the problem]" (p.13). The heuristic methods used by skilled performers were modeled for the student. It should be noted that all of this demonstration occured in the context of having the student engage in whole-task performance or problem solving.

Application and integration were at the center of the model. "The heart of the 4C/ID model concerns the design of whole-task practice. . . . The design of information presentation [demonstration] is always subordinate to, although integrated with, the design of practice" (van Merriënboer, 1997, p. 170). The emphasis of the model was on a sequence of problems so that demonstration and application are an integrated whole rather than distinct phases. The model described in some detail both product-oriented problem formats and process-oriented problem formats. The model suggested that appropriate practice involves scaffolding of problems, but rather than leaving the definition of scaffolding somewhat unspecified, the model suggested how different types of problem formats relate to cognitive load and practice sequences that were likely to promote the most effective skill development. The whole-task practice model led the student toward a real-world task that van Merrienboer thought should promote maximum integration.

Schank—Learning by Doing

Shank's (Schank et al., 1999) model was clearly problem-centered with a very strong emphasis on the application phase of instruction. In this model there was limited emphasis on activation and demonstration and, while integration was certainly the goal, there was very little in the model to direct the integration process per se. "GBS [goal-based scenario] is a learn-by-doing simulation in which students pursue a goal by practicing target skills and using relevant content knowledge to help them achieve their goal"

(p. 165). "There are seven essential components of a GBS: the learning goals, the mission, the cover story, the role, the scenario operations, the resources, and the feedback, including coaches and experts" (p. 173).

Scenarios (problems) were carefully defined. "[T]he first step in creating a GBS is determining a goal or mission that will be motivational for the student to pursue. . . . The cover story is the background story line that creates the need for the mission to be accomplished. . . . the most important thing to consider is whether the story will allow enough opportunities for the student to practice the skills and seek the knowledge you wish to teach. . . . The role defines who the student will play within the cover story. . . . it is important to think about what role is the best in the scenario to practice the necessary skills" (Schank et al., 1999, p. 173–175).

Schank et al., stressed that new cases (memories) are developed from existing cases (memories). Activation is elicited via *stories*. "The memories that contribute to our library of cases [memories] are of specific events in the form of stories. . . . the best way to convey information is . . . to embed lessons in stories [portrayal] that the learner can understand as an extension of the stories he or she already knows [activation]" (1999, p. 177).

Demonstration was provided within the context of the scenario. "[T]he resources we provide are usually experts telling stories about the information the student needs [demonstration]" (Schank et al., 1999, p. 177). "Information is provided primarily via feedback during the operation of the scenario in three ways: . . . consequence of actions . . . coaches . . . [who] provide . . . a just in time source to scaffold the student through tasks . . . and domain experts who tell stories that pertain to similar experiences" (p. 178).

"The scenario operations [application] comprise all of the activities the student does in order to work toward the mission goal" (Schank et al., 1999, p. 175). "The scenario operations should . . . have consequences that become evident at various points throughout the student interaction. . . . It is important that . . . little time be spent talking to the student about the scenario, and much more time be spent with the student practicing the skills and learning the information that comprise the learning goals" (p. 176).

The model did not address integration directly but assumed that, if the mission is motivating and of interest to the student, the student will internalize the case (memories) and it will be available in later real-world or other instructional scenarios.

CONCLUSION

Do the theories and models reviewed in this paper involve fundamentally different first principles? The answer appears to be no.

- All the theories and models reviewed incorporate some of these principles.
- No theory or model reviewed includes all of these principles.
- Some theories and models reviewed include principles or prescriptions that are not described in this paper. These represent areas for further investigation.
- No theory or model reviewed includes principles or prescriptions that are contrary to those described in this paper.

How do these theories and models differ?

The vocabulary used to describe these theories and their implementation details vary significantly.

These theories and models tend to emphasize different principles. Gardner (1999) stressed public exhibition of understanding (integration) and different kinds of intelligence (which is not included in the prescriptions of this paper). Nelson (1999) emphasized collaboration (which is not included in the prescriptions of this paper). Collaboration is emphasized by a number of current models, especially constructivist models. I agree that collaboration is a very important implementation of activation and integration but I am not yet convinced that collaboration is a first principle. Jonassen (1999) emphasized problem solving in learning environments. Van Merriënboer (1997) emphasized problem sequence and the sequence of supporting information. Schank (Schank et al., 1999) emphasized stories (a form of demonstration) and problem solving (cases).

This survey of instructional theories and models demonstrates that these theories do include first principles of instruction that are similar, regardless of theory or philosophical orientation. □

M. David Merrill [merrill@cc.usu.edu] is a Professor in the Department of Instructional Technology at Utah State University.

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