First Principles of Instruction

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Recent years have seen a proliferation of instructional design theories and models. Tennyson et al (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?

Reigeluth (1999) distinguishes two major kinds of instructional methods: basic methods and variable methods. First principles is an attempt to identify what Reigeluth calls basic methods but which the author prefers to call first principles. The author will refer 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 methods). 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 theory may specify both principles and practices for implementing these principles. In 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 facilitated 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[2]? Third, first principles of instruction are design oriented rather than learning oriented. They relate to creating learning environments and products rather than describing how learners acquire knowledge and skill from these environments or products.

The premise of this paper is that first principles for instruction do exist and that one or more of these first principles can be found in most instructional design theories and models. 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, research will demonstrate that when a given instructional program or practice violates or fails to implement one or more of these first principles, there will be a decrement in learning and performance. Our survey of instructional products also demonstrates that many instructional programs fail to effectively incorporate all of these principles.

The hypotheses of this paper are that:

1. Learning from a given instructional program will be facilitated in direct proportion to the implementation of first principles of instruction.
2. Learning from a given instructional program will be facilitated in direct proportion to the degree that first principles of instruction are explicitly implemented rather than haphazardly implemented.

The author is engaged in a program of scholarly research in an attempt to identify these first principles of instruction. His method of inquiry involves the following activities. (a) Analyze instructional theories, models, programs, and products to extract general first principles of instruction. (b) Identify the cognitive

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[2] Clark (1998) specified four architectures of instruction: receptive (e.g. lecture), directive (e.g. cbt tutorial), guided discovery (e.g. simulation) and exploratory (e.g. collaborative problem solving).

processes associated with each principle. (c) Identify empirical support for each principle. (d) Describe the implementation of these principles in a variety of different instructional theories and models. And (e) identify prescriptions for instructional design associated with these principles. This paper is a first attempt to communicate a first draft of our findings. The instructional principles stated in this paper are instructional prescriptions not principles of learning or cognition. They are prescriptive in form and are directed at instructional design practice.

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 vary significantly. A detailed discussion of implementation details is beyond the scope of this paper. Each of the theories and models reviewed here tend to emphasize different principles.

Our approach in this paper is to provide a concise statement of our current version of these first principles of instruction and then review selected theories to see how these principles are incorporated into 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. Not every principle may be included in the theories reviewed in this paper. A more complete analysis of these and other theories will be left to the author's more complete analysis that is in preparation.

Instructional phases

Many current instructional models suggest that the most effective learning environments are those that are problem-based and involve the student in four distinct phases of learning: (1) activation of prior experience, (2) demonstration of skills, (3) application of skills, and (4) integration or these skills into real-world activities. Figure 1 illustrates these five ideas. Much instructional practice concentrates primarily on phase 2 and ignores the other phases in this cycle of learning.

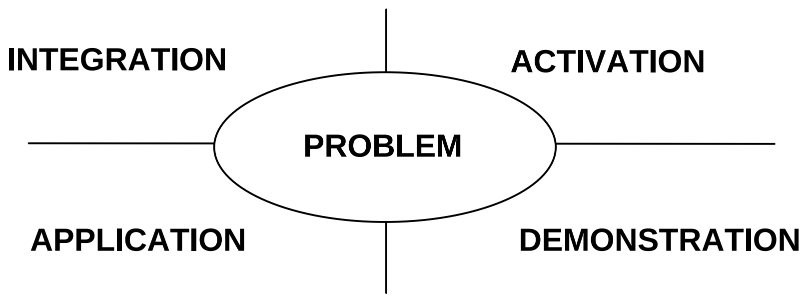

Figure 1 First Principles of Instruction Diagram

At the top level the instructional design prescriptions based on first principles are as follows:

- Learning is facilitated when learners are engaged in solving real-world problems.
- Learning is facilitated when existing knowledge is activated as a foundation for new knowledge[3].
- Learning is facilitated when new knowledge is demonstrated to the learner.
- Learning is facilitated when new knowledge is applied by the learner
- Learning is facilitated when new knowledge is integrated into the learner's world.

[3] The author used the word knowledge is 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.

Vanderbilt Learning Technology Center -- Star Legacy

The Learning Technology Center at Vanderbilt (Schwartz et al, 1999) describe Star Legacy, a software shell for instruction. The Vanderbilt approach is a good illustration of 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.

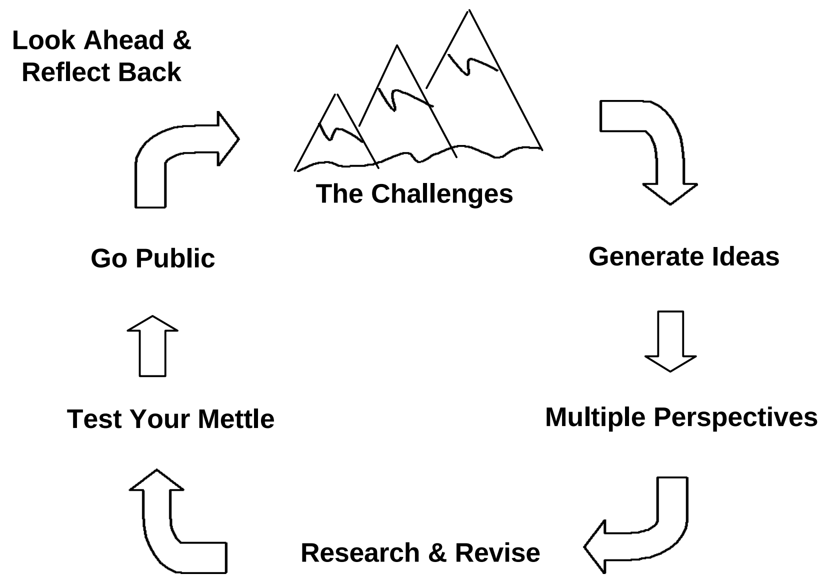

Figure 2 Learning Cycle of Star Legacy

Look ahead provides the learning context and learning goals. The *challenges* are problems to be solved. They use the metaphor of successively higher mountains to represent a progression of increasingly difficult challenges. *Generate ideas* is an activation activity where learners interact with other learners to share experience and what they already know related to the challenges. *Multiple perspectives* is an opportunity for the student 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 may need to solve the problem are demonstrated. *Research and revise* continues the demonstration phase and moves into the application phase in that the students gather lots of 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 get 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 made as explicit as in Star Legacy.

McCarthy -- 4-MAT

McCarthy (1996) is not included in the Reigeluth book but represents 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 in that she also makes the learning cycle very explicit. McCarthy approached this idea from a consideration of student learning styles but concluded that while learners may have preference for various approaches to learning that effective instruction requires students to be involved in the whole cycle of learning activities. Figure 3 illustrates some of the ideas that she emphasizes in her 4-MAT approach.

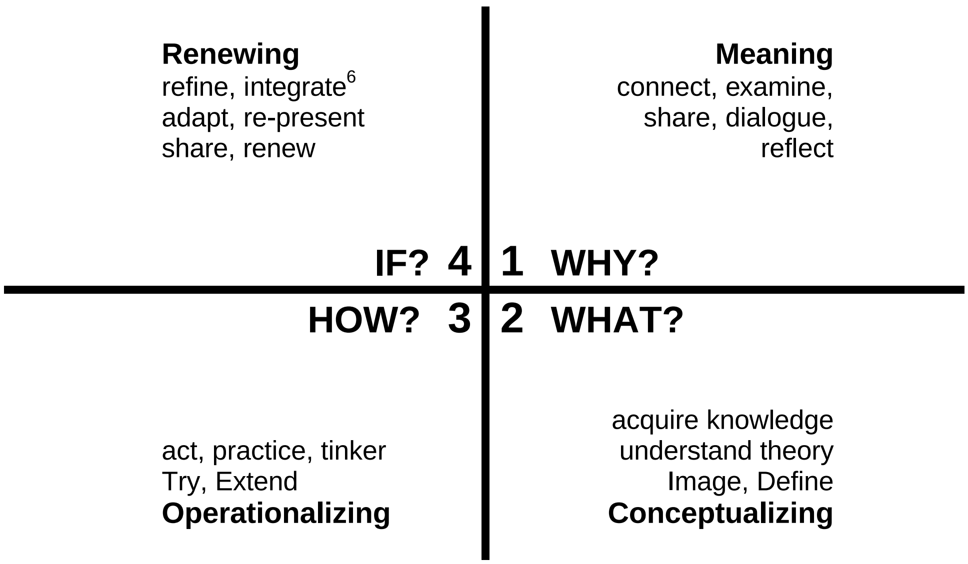

Figure 3 McCarthy 4-MAT Cycle of Learning

McCarthy does not emphasize problem solving as much as the Learning Technology Center. Her emphasis is 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 one serves the role of activation in which the students share what they know and try to find meaning related to the new material they will learn. 4-MAT phase one is very much like 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 students acquire new knowledge and relate it to what they already know. McCarthy (1996) includes sub-phases the description of which is beyond the scope of this 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 students use what they know to do something, make something, or play with the ideas. This phase is very related to the Star Legacy Research and Revise and Test Your Mettle components. McCarthy phase 4 is where the student makes the knowledge their own. This is the integration phase of our first principles. Our formulation of the learning cycle for first principles and our graphic representation of these phases was very influenced by McCarthy's work. She provides perhaps the most explicit articulation of the cycle of learning and the phases required for effective instruction.

Andre -- Instructional Episode

Andre (1997) work is focused more on the research supporting instruction rather than a theory per se. He describes an instructional episode consisting of three major groups: activation phase[7], instructional phase, and feedback phase. For Andre the instructional phase consists of presentation, discovery and practice (our application phase). His feedback phase is only part of the application phase as we have described it. Andre does not emphasize problem solving nor integration following the practice/feedback phase.

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[6] We used the term *integration* from McCarthy's work.
[7] We used the term *activation* from Andre's work.

Instructional Prescriptions from First Principles

In the following paragraphs the author elaborates each of these phases and suggests some specific prescriptions that have been identified from an examination of various theories, models and methods. The primary prescription and its corollaries are concisely stated first and the following paragraphs elaborate each of these prescriptions. These prescriptions have been derived from multiple sources. Specifically identifying these various sources and explaining our rational for the vocabulary we have chosen to express each of these prescriptions is beyond the scope of this paper[8]. Identifying the research support for these various prescriptions is also beyond the scope of the present paper. In the elaboration of each prescription the author has included some representative sources that support the prescriptions described[9]. In the later part of this paper the author attempt to illustrate the presence of some of these principles in a variety of different instructional theories.

Problem

Learning is facilitated when learners are engaged in solving real-world problems.

> Learning is facilitated 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.
>
> Learning is facilitated when learners are engaged at the problem or task level not just the operation or action level.
>
> Learning is facilitated when learners solve a progression of problems that are explicitly compared to one another.

Much of the current work in cognitive psychology has shown that students learn better when engaged in solving problems. Problems should be authentic, real world, and, if possible, personal. Problem based learning is well represented by a number of recent instructional models including: Collins et al (1989) Cognitive Apprenticeship; Schank et al (1999) Goal Based Scenarios; Jonassen (1999), Constructivist Learning Environments; Savery & Duffey (1995) Problem Based Learning; Clark & Blake (1997) Novel Problem Solving; and van Merriënboer (1997) Whole Task Practice in 4C/ID Model.

Showing learners the task or problem they will be able to solve is more effective than stating abstract learning objectives.

Learning to solve a problem involves four levels of instruction: the problem, the tasks required to solve the problem, the operations that comprise the tasks, the actions that comprise the operations. Effective instruction must engage students in all four levels of performance: the action-level, the operation-level, the task-level, and the problem level. Too much instruction is limited to the action or operation level and does not involve learners in the more integrative task or problem levels.

Some of the problems that students must learn to solve are very complex. A sink-or-swim approach is likely to discourage students. To master a complex problem students must first start with a less complex problem. When the first problem is mastered then students are 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. In too much instruction, even when it is problem-oriented, students are given only a single problem. Learning is best when there is a progression of problems to solve and when the problems start easy and then get harder and harder. Elaboration Theory (Reigeluth, 1999) is a model advocating a progression of successively more complex problems. van Merriënboer's 4C/ID Model (van Merriënboer, 1997) stresses the importance of a progression of carefully sequenced problems.

Sometimes it is difficult to find a simple version of a complex problem. In this situation the coach must actually do some of the problem solving for the students and assist the students to accomplish the remaining tasks or operations. With each successive problem the coach does less and less, while requiring students to do more and more, of the operations and tasks required. Gradually students are engaged in the

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[8] The author will present this detail in book form at a later date.

[9] These sources are representative rather than exhaustive. A more complete list of sources will be included in the author's book on this subject.

entire problem solving enterprise. Learning is best when there is a series of problems to solve and when coaching is gradually withdrawn for each succeeding problem.

When successive problems are directly compared with each other students are able to tune their mental model of the problems and build a better abstract mental model that is more likely to transfer to new problem situations. Gentner & Namy (1999) have demonstrated that the explicit comparisons of successive problems both for analogies and similar problems facilitates performance.

Activation

Learning is facilitated when relevant previous experience is activated.

> 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.
>
> Learners are provided relevant experience that can be used as a foundation for the new knowledge.
>
> Learners are given the opportunity to demonstrate their previously acquired knowledge or skill

It has long been a tenant 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. Andre (1997) provides one of the best recent discussions of activation. He also acknowledges that "A highly discussed procedure for schema activation is the use of advance organizers [Ausubel 1960, 1963]. Unfortunately, probably no single topic in educational/instructional research has generated both more interest and more ill-conceived research than that of advance organizers" (p. 247).

Activation is more than merely testing prerequisite knowledge. It is activating those mental models that can be modified or tuned to enable learners to incorporate the new knowledge into their existing knowledge. There is a current emphasis on introducing "themes" into instruction, for example, playing golf, flying a space ship, etc. When these themes are irrelevant to the content of the instruction they activate inappropriate mental models and may actually interfere with, rather than facilitate, instructional effectiveness. In an attempt to promote motivation these themes may actually increase the cognitive load required to acquire the target knowledge.

When learners feel 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 a 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.

Demonstration

Learning is facilitated when the instruction demonstrates what is to be learned rather than merely telling information about what is to be learned. …

> Learning is facilitated when the demonstration is consistent with the learning goal: (a)examples and non-examples for concepts, (b) demonstrations for procedures, (c) visualizations for processes, and (e) modeling for behavior.
>
> Learning is facilitated 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.
>
> Learning is facilitated when media plays a relevant instructional role.

Knowledge to be learned exists at two levels: the general-level and the specific-level. Too often information is presented at the general level rather than at the specific level of examples. Learning is best when students are shown (examples) rather than told (generalities).

A fundamental purpose of instruction is to promote the development of appropriate mental models for solving problems. A mental model is a cognitive structure and associated cognitive processing required for solving a class of problems (Mayer, 1992). Dijkstra & van Merriënboer (1997) identify three classes of problems: problems of categorization, problems of design (plans and procedures), and 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 (Merrill, 2000). Merrill (1994, 1997) identifies the knowledge structure, presentation, practice, and learner guidance for each of these different kinds of learning outcomes that are consistent with this kind of learning. Learning is facilitated when the information is consistent with the learning goal. Instructional consistency was stressed by Gagné (1965, 1985) and elaborated by Merrill (1994). van Merriënboer (1997) has extended this work in the context of problem-based instruction. The consistency criterion should be applied first. If demonstrations are inconsistent then it doesn't matter if there is learner guidance or if the media is relevant.

One role of instruction is to provide appropriate learner guidance to facilitate learning. One form of guidance is to focus students' attention on relevant information. 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. Learning is facilitated when learners are directed to important information and when this direction is gradually faded (Andre, 1997).

Another form of guidance is to provide learners with multiple representations of the ideas being taught and the demonstration being provided. Spiro & Jehng (1990), Schwartz et al (1999) and Clark & Blake (1997) all stress the importance of alternative points of view, especially for ill-defined domains and non recurrent skills. Gentner & 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.

Media plays two important roles. First, media represents referents in the real world. Effective instruction depends on these representation roles to be complete and appropriate. Second, media is a delivery system to convey the instruction to the student. A wide variety of delivery systems are available and all have a role to play. When used appropriately one delivery system is unlikely to be more effective than another. Gratuitous illustrations make little or no instructional contribution and are often ignored or may interfere with efficient learning.

Application

Learning is facilitated when learners are required to use their new knowledge or skill to solve problems.

> Learning is facilitated 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, name, and/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.
>
> Learning is facilitated 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.
>
> Learning is facilitated when learners are required to solve a sequence of varied problems.

No one would expect an athlete or musician to perform without hours of practice. Yet, much instruction seems to assume when it comes to cognitive skills that such practice is unnecessary. Appropriate practice is the single most neglected aspect of effective instruction. Answering multiplechoice questions may be consistent with recall of information, but information recall should always be a supportive objective rather than a terminal objective. Learning is facilitated when learners are required to use their newly acquired knowledge or skill.

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) identify appropriate practice for each of the kinds of knowledge and skill identified. Learning is facilitated 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 doesn't matter whether or not there is appropriate coaching and feedback or a sequence of problems.

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).

Just as practicing a scale once is insufficient for learning a musical skill, so applying knowledge to a single problem is insufficient for learning a cognitive skill. Adequate practice provides multiple opportunities for learners to use their new knowledge or skill for a variety of problems.

Integration

Learning is facilitated when learners are encouraged to integrate (transfer) the new knowledge or skill into their everyday life.

> Learning is facilitated when learners are given an opportunity to publicly demonstrate their new knowledge or skill
>
> Learning is facilitated when learners can reflect-on, discuss, and defend their new knowledge or skill.
>
> Learning is facilitated when learners can create, invent, and explore new and personal ways to use their new knowledge or skills.

Much is said 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. When learners are able to demonstrate improvement in skill, they are motivated to perform even better. It is the ability to show a new skill or an improvement in a skill that provides motivation. Learning is facilitated when learners can demonstrate skill improvement.

Knowledge and skill is soon forgotten if it is not made a part of the learner's life beyond instruction. Often skills need to be adapted or modified to fit into the learner's world. Learners needs the opportunity to reflect on, defend, and share what they have learned if it is to become part of their available repertoire.

A brief analysis of representative instructional theories

The following very brief analysis of some representative instructional theories is based primarily papers in Reigeluth (1999) and not on a comprehensive review of the theory from multiple sources. The analysis therefore may fail to account for theoretical ideas that may have been expressed in other papers about a particular theory. I have quoted these authors to provide the reader with the vocabulary of the theorists so that the reader can see first hand how these statements have been interpreted as representative of the first principles outlined in this paper.

Gardner -- Multiple Approaches to Understanding

Gardner's (1999) *performance approach to understanding* emphasizes understanding content ("important questions and topics of the world" p. 73) rather than problem solving, but his approach does embrace each of the four phases of instruction as described in this paper. He stresses that understanding can only be observed when students engage in "…performances that can be observed, critiqued, and improved" (p. 73). Understanding is not equated with problem solving. Problem solving per se does not seem to be emphasized by his approach.

He organizes his theory around phases he identifies 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 describes entry points from these six viewpoints: narrational, quantitative/numerical/ foundational/existential/ aesthetic, hands-on, and social.

Telling analogies forms a transition from activation to demonstration. "… come 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. "… portray 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 stresses application. "… multiple 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). While emphasizing multiple approaches based on multiple intelligences, in this paper Gardner does emphasize entry points and multiple approaches to the topic consistent with different kinds of intelligences, however, in this paper, he does not explicitly identify practice consistency with these different intelligences.

Perhaps the primary emphasis of Gardner is 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 emphasizes problem solving and includes all of the phases but more emphasis on application and less emphasis on demonstration. She attempts 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 provides 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, and (9) provide closure (see 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 2, 4 and 9). The author sees collaboration as one way to implement first principles and thus the activity guidelines for collaboration provided by Nelson are viewed as implementation guidelines rather than first principles.

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

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

She provides guidelines for gathering information that may be required for the problem solving process. The author views 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. [d] Collaborate with instructor to acquire additional resources and skills needed" (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. … [h] Evaluate the products and artifacts created" (p. 258).

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

Jonassen -- Constructivist Learning Environments (CLE)

Jonassen's (1999) approach emphasizes problem solving and includes all four phases of instruction. The primary emphasis of CLEs is problem solving as reflected by 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). "… 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 recommends 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 is 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" (p. 223).

Demonstration is 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" (p. 231). "A widely recognized method for modeling problem solving is worked examples" (p. 232).

Application is also stressed with an emphasis on coaching and scaffolding. "… in 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." (p. 232). "The most important role of the coach is to monitor, analyze, and regulate the learners' development of important skills" (p. 233). He "… 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 is 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) provides 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 integrates more directive approaches to instruction with problem-based approaches all in the context of what is known about cognitive processing. The model describes multiple approaches to analysis and how the products of these various analysis techniques lead to instructional design that all focus on whole task practice. This short summary is inadequate to illustrate the comprehensive nature of this model.

The model is 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 non-recurrent constituent skills, which require highly variable performance over situations" (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 non-recurrent aspects of the task" (p. 10).

van Merriënboer's model does 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 address some of the concerns of activation.

Demonstration is 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 …" (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 are modeled for the student. It should be noted that all of this demonstration occurs in the context of having the student engage in whole task performance or problem solving.

Application and integration are 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" (p. 170). The emphasis of the model is on sequence of problems so that demonstration and application are an integrated whole rather than distinct phases. The model describes in some detail both product-oriented problem formats and process-oriented problem formats. The model suggests that appropriate practice involves scaffolding of problems, but rather than leaving the definition of scaffolding somewhat unspecified, the model suggests how different types of problem formats relate to cognitive load and practice sequences that are likely to promote the most effective skill development. The whole-task practice model leads the student toward a real-world task that van Merrienboer feels should promote maximum integration.

Schank -- Learning by Doing

Shank's (1999) model is clearly problem centered with a very strong emphasis on the application phase of instruction. In this model there is limited emphasis on activation and demonstration and, while integration is certainly the goal, there is 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" (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" (173).

Scenarios (problems) are carefully defined. "…the 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" (p. 173-175).

Schank et al stress 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 that the learner can understand as an extension of the stories he or she already knows" (p. 177).

Demonstration is provided within the context of the scenario. "… the resources we provide are usually experts telling stories about the information the student needs" (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" (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 does not address integration directly but assumes that if the mission is motivating and of interest to the student that the student will internalize the case (memories) and that it will be available in later real-world or other instructional scenarios.

Findings to date

Do the theories and models reviewed in this paper involve fundamentally different first principles?

(1) All the theories and models incorporate some of these principles. (2) No theory or model includes all of these principles. (3) Some theories and models include principles or prescriptions that are not described in this paper. These represent areas for further investigation. And (4) no theory or model 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 the implementation details vary significantly. A detailed discussion of implementation details is beyond the scope of this paper.

These theories and models tend to emphasize different principles. Gardner stresses public exhibition of understanding (integration) and different kinds of intelligence (that is not included in the prescriptions of this paper). Nelson emphasizes collaboration (that is not included in the prescriptions of this paper). Collaboration is emphasized by a number of current models especially constructivist models. The author agrees that collaboration is a very important implementation of activation and integration but he is not yet convinced that collaboration is a first principle. Jonassen emphasizes problem solving in learning environments. Van Merriënboer emphasizes problem sequence and the sequence of supporting information. Schank emphasizes stories (a form of demonstration) and problem solving (cases).

Conclusion

This paper is a preliminary report. Nevertheless, the survey of instructional theories and models to date seems to demonstrate that there are first principles of instruction that are similar regardless of theory or philosophical orientation. This paper has not reported empirical verification of these principles but a preliminary survey of this data seems to justify the hypothesis that failure to implement these first principles in instructional programs and practices will cause a decrement in learning. Or stated more positively, as an instructional program implements more of these principles, then there will be a corresponding increase in the quality and amount of learning that will occur. Much remains to be done in articulating these first principles and tracing their role in different theories. The author invites your response and participation in this enterprise.

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