Chapter 3

Some Major Sequencing Strategies: Understanding the Theories

This chapter provides an understanding of some of the major sequencing strategies: procedural, hierarchical, simplifying conditions, conceptual elaboration, and theoretical elaboration.. Chapters 4-8 deal with how to design, and conduct analyses for, each of these four kinds of sequences. I recommend you get a firm understanding of each sequencing strategy in this chapter before you go to its "how to" chapter. But you might want to choose to study both the "theory" and the "how to" for one sequencing strategy before you study any other strategies. In either event, I strongly recommend you learn about the hierarchical sequence before any of the others, because it is utilized by all the others. And it is important to understand the procedural sequence before you learn about the SCM sequence, for the same reason. Other than that, it doesn't matter much what order you learn about them.

Hierarchical Sequence

What Is a Hierarchical Sequence?

Robert Gagné developed the hierarchical sequence for teaching "intellectual skills" in the cognitive domain. Intellectual skills are domain-dependent skills—skills that pertain to a single subject area, or domain—and are contrasted with "cognitive strategies," which are domain-independent skills—ones that can be applied across domains, such as critical thinking skills.

The hierarchical sequence is based on the observation that a skill is made up of simpler "component skills" that you must learn before you can learn the larger, more complex skill of which they are a part. For example, you must learn to multiply and subtract whole numbers before you can learn how to do long division (see Figure 3.1). So basically the sequencing strategy is that, if one skill has to be learned before another can be learned, teach it first. It's that simple—in theory. But not exactly in practice.

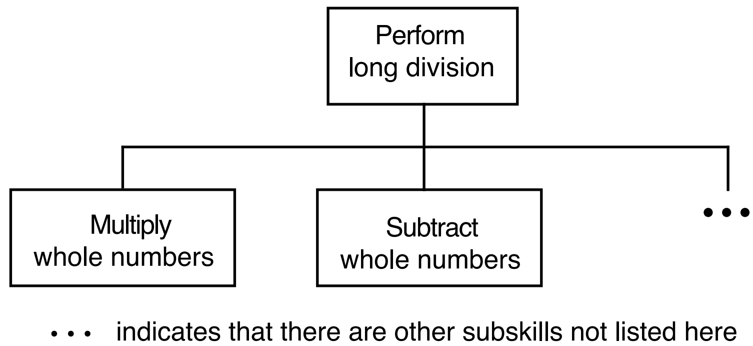

Figure 3.1 A learning hierarchy in which the lower skills must be learned before the higher skill can be learned. (The entire hierarchy is not shown.)

How do you figure out what the prerequisite skills are? This is the purpose of a **hierarchical task analysis**. To help with that task, Gagné has identified a variety of kinds of skills that are prerequisites for each other. They are shown in Figure 3.2.

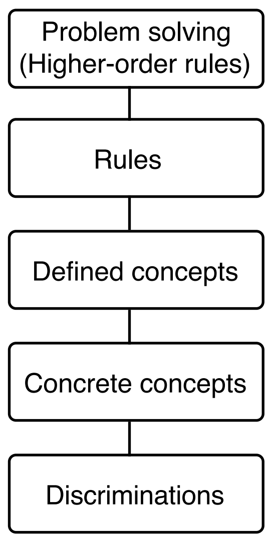

Figure 3.2 A hierarchy of intellectual skills (from Gagné, 1965).

The skill for a **discrimination** is the ability to tell the difference between "stimuli that differ from one another along one or more physical dimensions" (Gagné, Briggs & Wager, 1992, p. 56). For example, one particular discrimination is being able to tell the difference between a triangle and a rectangle. It does not require being able to label either. It differs from memorization (or Gagné's "verbal information") in that it requires some degree of generalization, such as being able to tell the difference between any triangle and any rectangle. The conclusion of the performance of this skill is usually saying whether two things are the same or different.

The skill for a **concrete concept** is the ability "to identify a stimulus as a member of a class having [an *observable* property] in common, even though such stimuli may otherwise differ from each other markedly" (Gagné, Briggs & Wager, 1992, p. 57). For example, one particular such skill is being able to identify any triangle as a triangle. Classifying a concrete concept differs from making a discrimination in that it requires naming or otherwise identifying a particular instance as belonging to a class, rather than just being able to say that the instance is different from, or the same as, something else. The conclusion of the performance of this skill is usually indicating whether or not something belongs to a given class of things.

The skill for a **defined concept** is the ability to identify a stimulus as a member of a class having a *definable* property in common, even though such stimuli may otherwise differ from each other markedly. Defined concepts include objects (such as a "pen"), events (such as a "fight"), and ideas (such as "justice"). For example, one particular such skill is being able to identify any polygon as a polygon. Note that I have made the definition of "defined concept" as similar as possible to the definition of "concrete concept" to highlight the difference. Defined concepts all have definitions, whereas many (but not all) concrete concepts do not (like the note, C, in music). Concrete concepts are all tangible in some way (they can be touched, seen, heard, etc.). However, the distinction between defined and concrete concepts is not always easy to make. According to Gagné, Briggs and Wager (1992),

> ... some defined concepts have corresponding concrete concepts that carry the same name and possess certain features in common. For example, many young children learn the basic shape of a triangle as a concrete concept. Not until much later in studying geometry do they encounter the defined concept of triangle, ... The concrete and defined meanings of *triangle* are not exactly the same, yet they overlap considerably. (p. 60).

It seems that the difference is "in the eye of the learner," as it were. If the skill is learned by generalizing from instances and the learner does not consciously use a definition to guide performance of the skill, then it is a concrete concept for that learner. But if the learner uses a definition (either invented by, or given to, him or her) to guide performance of the skill, then it is a defined concept for that learner.[1] As with concrete concepts, the conclusion of the performance of this skill is usually indicating whether or not an instance belongs to a given class of instances.

The skill for a **rule** is the ability to consciously or subconsciously apply the rule to new situations. A rule is "a *class* of relationships among *classes* of objects and events" (Gagné, Briggs & Wager, 1992, p. 61). I find it useful to think in terms of two major kinds of rules: procedural rules and heuristic rules. A *procedural rule* is a set of steps for accomplishing a goal, such as the rule for multiplying fractions (first, multiply the numerators, then multiply the denominators, then ...). A *heuristic rule* is a principle or a guideline, such as the law of supply and

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[1] For instructional purposes, I don't see much value in the distinction between concrete and defined concepts, except that you cannot use a definition to help someone learn a concrete concept.

demand (an increase in price will cause a decrease in the quantity demanded and an increase in the quantity supplied, while a decrease in price ...). So what is the difference between a rule and a defined concept? As Gagné, Briggs, and Wager (1992) put it, "a defined concept is a particular type of rule whose purpose it is to classify objects and events; it is a *classifying rule*." (p. 62). A classifying rule may be either procedural (for well defined concepts, like "triangle") or heuristic (for fuzzy concepts, like "justice"). Very often, people are not consciously aware of the rules they use—they cannot actually state the rules that govern their thinking and behavior, particularly experts. This is what Polanyi referred to as tacit, as opposed to explicit, knowledge. And this is why experts are often not the best teachers of novices. The conclusion of the performance of this skill is usually the attainment of a specific goal for a specific situation.

The skill for a **higher-order rule** is the ability to consciously or subconsciously apply a higher-order rule to new situations. A higher-order rule is "a complex combination of simpler rules" (Gagné, Briggs & Wager, 1992, p. 63). Higher-order rules may also be procedural or heuristic. The act of inventing a higher-order rule is called *problem solving*, but once it is invented by, or given to, the learner, then it becomes an act of rule using (or more accurately, higher-order rule using) rather than problem solving. The difference between a higher-order rule and a rule is simply one of complexity: a higher-order rule is a rule that combines several simpler rules. An example of problem-solving is figuring out the area of an irregularly shaped figure for the first time. The conclusion of the performance of this skill is usually the attainment of a specific goal for a specific situation.

The hierarchical arrangement of these skills (shown in Figure 3.2) helps you to figure out what prerequisites any given skill might have, but it can also be misleading, because it is not true that a skill on one level *only* has prerequisites on the next lower level. In fact, any given skill usually has many levels of prerequisites on the very same level of Gagné's hierarchy. For example, the skills on both levels 1 and 2 in Figure 3.1 are rules (or higher-order rules), and each of the rules on level 2 has its own prerequisite rules (e.g., "being able to carry a 10"), as well as its prerequisite concepts (e.g., "whole number"). It is fairly common to have 5-10 levels of rules in a hierarchical analysis of a complex skill, and 2 or 3 levels of defined concepts. So a typical learning hierarchy might look more like Figure 3.3, which is a minor modification of a hierarchy developed by Robert Gagné himself (see Gagné, 1968, p. 184). It is important to keep in mind that the accuracy of a learning hierarchy can only be determined by testing learners from the target population. If it turns out that learners were able to master one skill without acquiring one connected below it, then the lower one should be removed from there.

But a hierarchical analysis could go on seemingly forever. How far down should you continue to break skills into subskills? Since the purpose of a hierarchical analysis is to identify the prerequisite skills that need to be

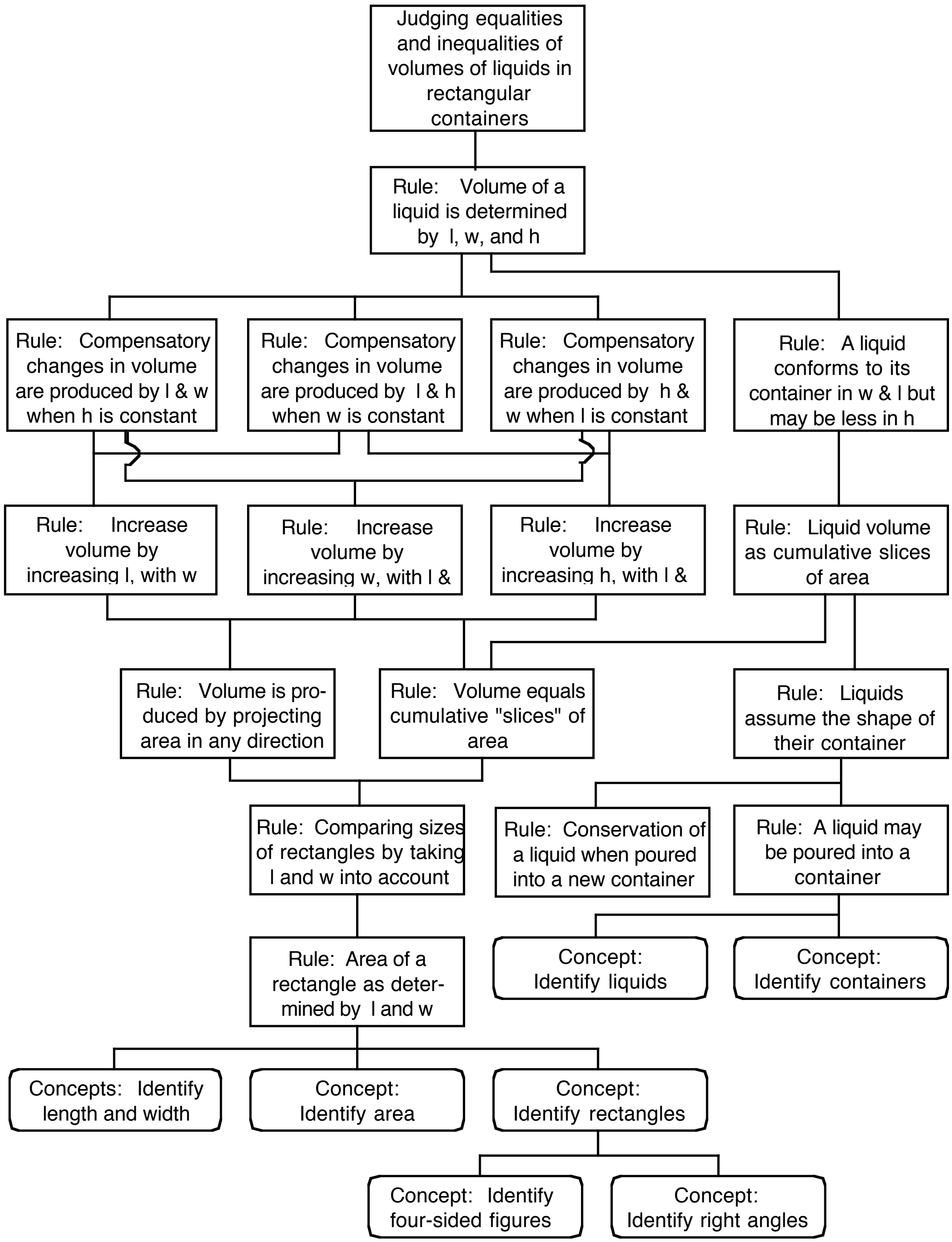


Figure 3.3 The results of a hierarchical task analysis (modified from Gagné, 1968)

taught (and the order of the prerequisite relationships among them), you don't want to go down beyond the skills that need to be taught. Clearly, skills the learner has already mastered don't need to be taught. So you only need to do your analysis down to the level of **entering knowledge** of the learner. Keep in mind that each individual skill becomes simpler the further down you go in your analysis, even though each level down is a more complex description of the overall skill being analyzed. This is what I call the hierarchical paradox. Simpler is more complex.

A **hierarchical sequence**, then, is one which never teaches a skill before its prerequisites (ones immediately below it and connected to it by a line). You could take a spiral approach to hierarchical sequencing by teaching all the skills on the bottom level of the hierarchy, then moving across the next level up, and so forth. Or you could take a topical approach by moving as far up a "leg" of the hierarchy as quickly as possible for one module of instruction, and then moving on to other "legs" in other modules, always trying to get as high up as you can as soon as you can. Other options are possible, some of which we will look at when we explore the other sequencing strategies in this chapter.

When and Why To Use It?

The strengths of the hierarchical sequence are:

- In situations where one skill must be learned before another can be learned, it is extremely important, for any sequence that violates it is, by definition, doomed to failure (for a learning prerequisite is defined as a skill that must be mastered before it is possible to master a more complex skill of which it is a part).
- The hierarchical sequence is fairly broadly applicable, because skills of one kind or another are a major component of most courses in both education and training contexts.
- The sequence is very easy to design once the analysis has been done, and the analysis is not difficult to do, nor to learn to do.

The limitations of the hierarchical sequence are:

- By breaking skills into simpler component parts, the instruction is fragmented, which can be demotivating for the learner and impede valuable schema formation.
- Since it applies to sequencing instruction for a single skill or set of prerequisite (or overlapping) skills, it offers no guidance as to how to sequence skills where one is not a part of the other and is therefore seldom useful for broader sequencing decisions in a large course or curriculum.
- Since it only applies when one skill must be learned before another can be learned, it doesn't provide any guidance as to how to handle "soft" prerequisites, that is, skills that facilitate learning another skill, but aren't absolutely necessary for learning it.
- Since it only applies to skills, it is not useful for courses in which

skills play a minor role.

The net effect is that hierarchical sequencing is not something that can be violated, but it is seldom sufficient alone for sequencing a course or training program. It can, however, be combined with other sequencing strategies, including all the remaining ones described in this chapter.

Procedural Sequence

What Is a Procedural Sequence?

As its name implies, the procedural sequence entails teaching the steps of a procedure in the order in which they are performed. Procedural sequences have probably been used (and fairly well understood) for millennia. They were systematically studied by the behaviorists in the late 1950's and the 1960's under the rubric of "forward chaining" sequences (see, e.g., Mechner, 1967). Methodology was further developed by cognitivists in the 1970's under the rubric of "information-processing" sequences (see e.g., Merrill, 1976; 1980; Resnick & Ford, 1980).

The procedural sequence is also based on a prerequisite relationship, only in this case it is a procedural prerequisite rather than a learning prerequisite. A procedural prerequisite is a step that must be *performed* before another step can be performed in the execution of a given task, whereas a learning prerequisite is a skill that must be *learned* before another skill can be learned.

To design a procedural sequence, therefore, you must first figure out the order in which the steps are performed (i.e., what the prerequisite steps are for each step). This is the purpose of a **procedural task analysis**, and it usually results in a flow chart of the steps that make up the procedure (see Figure 3.4 for an example). Sounds pretty straightforward and easy, right? Well, not exactly (Hertz, 1995). The problem relates to the hierarchical paradox. To teach someone how to fix cars, our procedural analysis could identify just two steps: 1) find out what's wrong with the car, and 2) fix it. Clearly, more analysis is needed. We can describe the task at different levels of detail, just like in a hierarchical analysis—that is, we can break steps down into substeps, just like we can break skills down into subskills. But steps and substeps are always higher-order rules or rules (specifically procedural rules rather than heuristic rules), never concepts or discriminations.

So, what we need to do is a hierarchical analysis in **combination** with the procedural analysis. We need to break each step down into substeps, and substeps into sub-substeps, and so on, until we reach the entry level of the

Create a flowchart of figure 3.5

Figure 3.4 An example of a flowchart.

learner. As with the hierarchical analysis, each level of description describes the same procedure, in its entirety, as the previous level did, only with more detail. And the more detailed the description of how to repair an automobile, the simpler each step is to do, even though the whole description seems more complex than our two-step procedure for fixing a car. (Hence the hierarchical paradox is alive and well in a procedural analysis.) Furthermore, we need to keep in mind that almost every step has at least one concept in it, so, once we reach entry level of description of the steps, we need to do a hierarchical analysis of those steps to identify any unmastered prerequisite concepts (and occasionally discriminations). So the result of a typical procedural analysis might look like Figure 3.5.

A procedural sequence, then, is one which teaches all steps in the order of their performance, after they have all been broken down to the entry level of the learner. Naturally, it is important to teach prerequisite concepts before teaching the steps in which those concepts are used. Such concepts are often the inputs, the outputs, or the tools for the steps.

Procedural Task Analysis:
Conducting a Needs Analysis
by Terry M. Farmer

Steps at highest level of description
1. Determine if a performance problem exists.
2. Identify boundaries of the performance gap.
3. Conduct a cost/benefit analysis.
4. Determine the cause(s) of the performance problem.
5. Classify the performance problem type.
6. Recommend solution(s) for the performance problem.

Step 4 broken down
4.1 Conduct a job analysis.
4.2 Did the job analysis clearly identify a cause of the performance gap? If yes, go to step 5.1. If no, go to Step 4.3.
4.3 Conduct a context analysis.
4.4 Did the context analysis clearly identify a cause of the performance gap? If yes, go to step 5.1. If no, go to Step 4.5.
4.5 Conduct an extant data analysis.
4.6 Did the extant data analysis clearly identify a cause of the performance gap? If yes, go to step 5.1. If no, go to Step 4.7.
4.7 Conduct a formal learner analysis.
4.8 Did the learner analysis clearly identify a cause of the performance gap? If yes, go to step 5.1. If no, exit.

Step 4.1 broken down
4.1.1 List the major components of the employee's job.
4.1.2 Break down the major parts into subparts.
4.1.3 List these components hierarchically.
4.1.4 Ask organization members to assist in identifying which parts or sub-parts are involved in the cause(s) of the performance problem.

Identification of concepts for step 4.1.3
Hierarchy, subordinate, coordinate, superordinate

Figure 3.5 The results of a procedural task analysis

When and Why to Use It?

The strengths of the procedural sequence are:

- In both training and education contexts much instruction in the cognitive and motor domains focuses on procedures—learning to follow a set of steps to achieve a goal. For such situations, a procedural sequence is logical to the learner, and the order of learning the steps helps the learner to remember their order of performance.
- Both the analysis and design of the sequence are very quick and easy, and don't require much training for the designer.

Because of these factors, the procedural sequence is one of the most common sequences for instruction.

The **limitations** of the procedural sequence are:

- The procedure must not be a very complex one, in the sense of having lots of decision steps and branches, because the methodology offers no guidance as to what to do when you come to a branch—which branch to follow first, or even whether to teach all of one branch before teaching parts of other branches.
- The content must be primarily procedural (a set of steps), because the sequence can't be applied to nonprocedural content.

The net effect is that the procedural sequence is simple and easy to use and quite effective for nonbranching procedures, but it is not sufficient for sequencing a complex branching procedure, nor is it appropriate for dealing with nonprocedural content. It can, however, be combined with other sequencing strategies, including the remaining ones described in this chapter.

Elaboration Sequences

The Elaboration Theory of Instruction was developed to provide holistic alternatives to the parts-to-whole sequencing and superficial coverage of content that have been so typical of both education and training over the past five to ten decades. It has also attempted to synthesize several recent ideas about sequencing instruction into a single coherent framework. It currently only deals with the cognitive and psychomotor domains, and not the affective domain.[2] It is founded on the notion that different sequencing strategies are based on different kinds of relationships within the content, and that different relationships are important for different kinds of expertise. So the kind of sequence that will most facilitate learning will vary depending on the kind of expertise you want to develop.

First, Elaboration Theory makes a distinction between task expertise and subject-domain expertise (see Figure 3.6). **Task expertise** relates to the learner becoming an expert in a specific task, such as managing a project, selling a product, or writing an annual plan. **Domain expertise** relates to the learner becoming an expert in a body of subject matter not tied to any specific task, such as economics, electronics, or physics (but often relevant to many tasks). This is not the same as the distinction between procedural and declarative knowledge (J.R. Anderson, 1983), for task expertise includes much declarative knowledge

[2] However, there are strong indications that it can be, and indeed is already intuitively being, applied in the affective domain. For example, Mark Greenberg and associates (Greenberg, Kusche, Cook, & Quamma, 1995) have developed the PATHS curriculum (Promoting Alternative THinking Strategies), an emotional literacy program designed to help children avoid the road to violence and crime. According to Goleman (1995), "the PATHS curriculum has fifty lessons on different emotions, teaching the most basic, such as happiness and anger, to the youngest children, and later touching on more complicated feelings such as jealousy, pride, and guilt." (p. 278).

and domain expertise includes much "how to" knowledge.

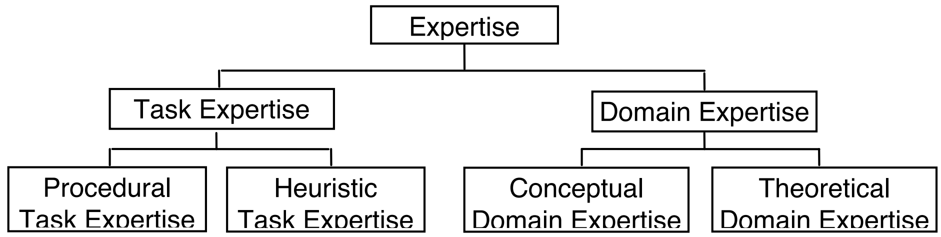


Figure 3.6 Kinds of expertise.

Task Expertise

Tasks range from simple to complex. The Elaboration theory is only intended for more complex tasks. It is based on the observation that complex cognitive tasks are done differently under different conditions, that each set of conditions defines a different version of the task, and that some of those versions are much more complex than others. For example, solving mathematical problems is easier when you are solving for one unknown than for two unknowns. The number of unknowns is a condition variable having two conditions: 1 unknown and 2 unknowns. And skills and understandings of differing complexity are required for each condition. So problems or projects that learners tackle should be ones that are within what Vygotskii (1986) called the "zone of proximal development"—close enough to the learner's competence for the learner to be able to deal with successfully with some help; and the problems should gradually increase in complexity. Thus, the Elaboration Theory offers the Simplifying Conditions Method to design a holistic, simple-to-complex sequence by starting with the simplest real-world version of the task and progressing (by amounts appropriate for the learner) to ever more complex versions as each is mastered.

But not all complex tasks are of the same nature. Some are primarily procedural, and some are primarily heuristic**. Procedural tasks** are ones for which experts use a set of mental and/or physical steps to decide what to do when, such as a high school course on mathematics or a corporate training program on installing a piece of equipment for a customer. **Heuristic tasks** are ones for which experts use causal models—interrelated sets of principles and/or guidelines—to decide what to do when, such as a high school course on thinking skills or a corporate training program on management skills).

Because **causal models** are so important to understanding the nature of heuristic tasks, I will discuss them a bit further. A causal model is an interrelated set of cause-effect relationships, in which there are chains of causes and effects and there are usually multiple causes of the effects and multiple effects of the causes (see Figure 3.7). These causal relationships are usually probabilistic rather than deterministic, meaning that the causal event will increase the probability of the effect occurring rather than necessitating (determining) that it will occur.

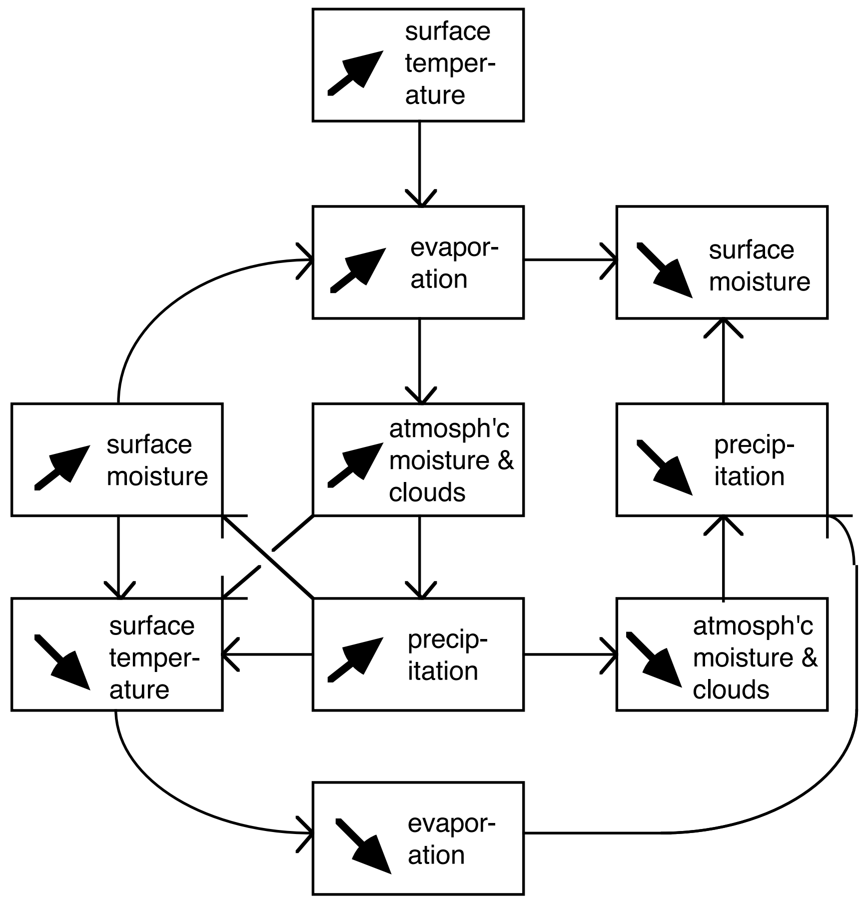


Figure 3.7 A partial example of a causal model related to the water cycle

Figure 3.7 shows one way of representing part of a complex causal model related to the water cycle. Each box shows a change—either an increase (shown by a rising arrow) or a decrease (shown by a declining arrow) in some activity or condition. The arrows between boxes show the direction of causality. So, looking at the top of the diagram, you would read that "an increase in surface temperature causes (or more accurately increases the probability of) an increase in evaporation."

Although some tasks are primarily procedural or primarily heuristic, most tasks are a combination of the two, somewhere on a continuum that ranges from purely procedural to purely heuristic tasks. The guidance offered by the SCM (Simplifying Conditions Method) is a bit different for the procedural than for the heuristic elements of a task, because what must be learned (the content) is very different, and the relationships within that content are very different.

Domain Expertise

Domain expertise ranges from simple to complex, but also from general to detailed. And it is the general-to-detailed nature of domain expertise that allows the design of a holistic sequence that goes from simple to complex. The Elaboration Theory's sequencing guidance for domain expertise was derived primarily from Bruner's (1960) "spiral curriculum" and Ausubel's (1968) "advance organizers" and "progressive differentiation," but it differs in several important ways from each and also provides greater guidance as to how to design such a sequence. A domain elaboration sequence starts with the broadest, most inclusive, most general ideas (which are also the simplest and generally the first to have been discovered), such as the law of supply and demand in economics and Ohm's law in electricity. And it gradually progresses to more complex, precise, ideas, such as those which relate to maximizing profits on the supply side (marginal revenues and marginal costs) and those which relate to consumer preferences on the demand side of the law of supply and demand. This makes an elaboration sequence ideal for discovery learning and other approaches to the construction of knowledge.

The Elaboration Theory recognizes two major kinds of domain expertise: **conceptual** (understanding what) and **theoretical** (understanding why). In their simplest form, these are concepts and principles, respectively, and in their more complex forms, they are conceptual knowledge structures (or concept maps) for "understanding what," and both causal models and theoretical knowledge structures (see Figure 3.5) for "understanding why." Although these two kinds of domain expertise are closely interrelated and are both involved to varying degrees in gaining expertise within every domain, the guidance for building a holistic, general-to-detailed sequence is different for each kind of domain expertise. Thus, the Elaboration Theory offers guidance for sequencing for both kinds of domain expertise, and both types of elaboration sequences can be used simultaneously if there is considerable emphasis on both types of domain expertise in a course. Again, this is referred to as **multiple-strand sequencing** (Beissner & Reigeluth, 1994).

What Is an Elaboration Sequence?

The Elaboration Theory has currently identified four types of sequences, one for each of the four types of expertise (see the table below). However, I anticipate that additional ones remain to be identified.

Kind of Expertise	Procedural Task Expertise	Heuristic Task Expertise	Conceptual Domain Expertise	Theoretical Domain Expertise
Kind of Sequence	Procedural SCM	Heuristic SCM	Conceptual Elaboration	Theoretical Elaboration

The Simplifying Conditions Method

For building task expertise, the Simplifying Conditions Method, or SCM, is a relatively new approach that offers guidance for analyzing, selecting, and sequencing the “what to learn” (content). Briefly, SCM provides practical guidelines to make a kind of simple-to-complex sequence that is very different from the hierarchical sequence, one that is holistic rather than fragmented. Given that any complex task has some conditions under which it is much easier to perform than under others, an SCM sequence begins with the **simplest version** of the task that is still fairly representative of the task as a whole. Then it moves to **progressively more complex versions** of the task until the desired level of complexity is reached, making sure that the learner is made explicitly aware of the relationship of each version to the other versions. Each version of the task is a class or group of complete, real-world performances of the task. This sequence contrasts sharply with the hierarchical sequence, which teaches all the prerequisites first and usually doesn't teach a complete, real-world task until the end of the sequence. Figure 3.8 (next page) shows the differences between the hierarchical approach and the SCM approach.

The SCM (for both procedural and heuristic tasks) is composed of two parts: epitomizing and elaborating. **Epitomizing** is the process of identifying the simplest version of the task that is still fairly representative of the whole task. **Elaborating** is the process of identifying progressively more complex versions of the task.

The principles of epitomizing are based upon the notions of holistic learning and schema-building. Therefore, epitomizing utilizes:

1) a whole version of the task rather than a simpler component skill,
2) a simple version of the task,
3) a real-world version of the task (usually), and
4) a fairly representative (typical or common) version of the task.

The epitome version of the task is performed by experts only under certain restricted conditions, referred to as the **simplifying conditions**, which are **removed** one by one to define each of the more complex versions of the task. Examples are provided on p. 6.8 and 6.14.

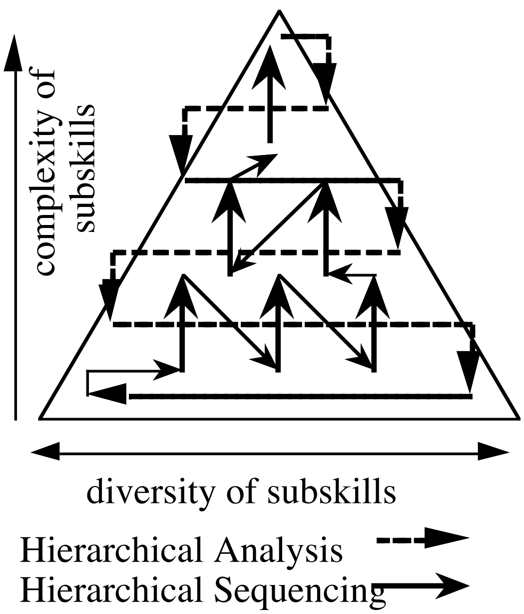
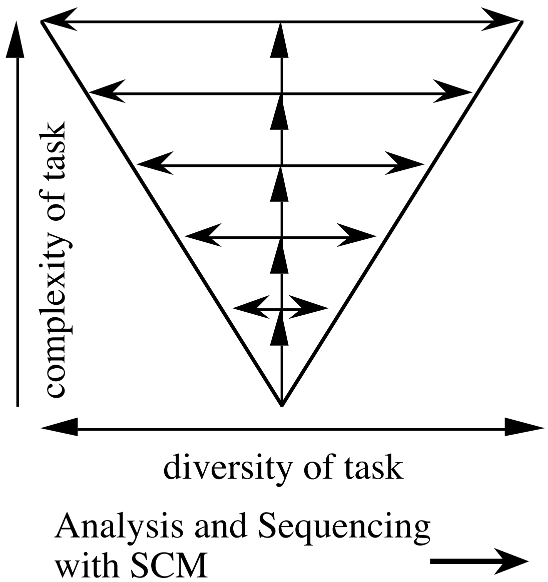
	Hierarchical Task Analysis and Sequencing	**Task Analysis and Sequencing with SCM**
Conceptual map	 	
underlying logic	Part to whole/Simple to Complex (Subskills to main skills)	Simple to complex (simple task to complex task)
For Designer	Task analysis should be done prior to sequencing as separate task.	Task analysis and sequencing can be done simultaneously. - the prototype can be developed rapidly.
For Learner	Facilitates the learning of higher-order skills.	From the very first lesson, it provides 1) the flavor of the whole task, 2) a simple but applicable skill, and 3) enhanced motivation.
The hierarchical approach is necessary but not sufficient. It also introduces a very fragmentary approach.		

Figure 3.8: Hierarchical Approach and the SCM Approach (From Reigeluth & Kim, 1993)

The principles of elaborating are similarly based on the notions of holistic learning and assimilation-to-schema. Therefore, each subsequent elaboration should be:

1) another whole version of the task,
2) a slightly more complex version of the task,
3) equally authentic (or more so), and
4) equally or slightly less representative (typical or common) of the whole task.

The principles of epitomizing and elaborating are operationalized a bit differently depending on whether you are developing procedural task expertise (through a procedural SCM sequence) or heuristic task expertise (through a heuristic SCM sequence).

The **procedural SCM sequence** (Reigeluth & Rodgers, 1980) was derived primarily from the work of Scandura (1973) and P. Merrill (1976, 1980) on "path analysis" of a procedure. Every decision step in a complex procedure signals at least two different paths through the flowchart of the procedure (one of which is almost always simpler than the others), and it also represents at least two different conditions of performance. The SCM sequence starts with the simplest real-world version (or path) of the procedural task (a version or path is a set of performances that are done under the same conditions) and gradually progresses to ever more complex versions as each is mastered. The example cited above was progressing
from one unknown to two unknowns in mathematical problems. Some different steps (meaning a different path, requiring different skills and knowledge) are required for each condition.

In contrast, the **heuristic SCM sequence** (Reigeluth, 1992; Reigeluth & Kim, 1993) is based on the observation that heuristic tasks are characterized by great variations in the nature of an expert's performance, depending on the conditions of performance—so much so that experts don't think in terms of steps when they perform the task. This sequencing methodology was derived by Reigeluth primarily from the procedural SCM sequence. Like the procedural SCM sequence, this one also starts with the simplest real-world version of the task and gradually progresses to ever more complex versions as each is mastered. The major difference lies in the nature of the content that is analyzed and sequenced. Rather than a set of steps (with decisions and branches and paths), you must attempt to identify the underlying principles or causal models that experts use to perform the task. Simpler versions of the task require simpler causal models for expert performance.

Both types of SCM sequences can be used simultaneously if the task is a combination of both types of knowledge (procedural and heuristic). And SCM and domain-elaboration sequences can be used simultaneously as well. These are referred to as **multiple-strand sequences** (Beissner & Reigeluth, 1994).

For domain expertise, the conceptual elaboration sequence is described next, followed by the theoretical elaboration sequence.

The Conceptual Elaboration Sequence

For building domain expertise, the conceptual elaboration sequence is one of two sequencing strategies offered by the Elaboration Theory. Both types of elaboration sequences can be used simultaneously if there is considerable emphasis on both types of content in a course. As mentioned above, this is referred to as **multiple-strand sequencing** (Beissner & Reigeluth, 1994). The conceptual elaboration sequence (Reigeluth & Darwazeh, 1982) is intended for courses that focus on interrelated sets of concepts, which are usually kinds and/or parts of each other. Examples include a high school biology course that focuses on kinds and parts of animals and plants and a corporate training program that focuses on the kinds and parts of equipment that the company sells. This sequencing methodology was derived primarily from Ausubel's (1968) "advance organizers" and "progressive differentiation" but provides greater guidance as to how to design that kind of sequence. The sequence starts with the broadest, most inclusive concepts and gradually progresses to their ever-more-narrow parts and/or kinds, one level of detail at a time. This can be done in either a topical or spiral fashion (see Figure 2.1 in Chapter 2).

The conceptual elaboration sequence is based on several observations. The first is that concepts are groupings or classes of objects, events, or ideas. For example, "tree" is a concept that includes all individual plants that meet certain criteria, most notably a woody stem. The second is that concepts can be broken down into narrower, less inclusive concepts that are either parts or kinds of them. For example, parts of trees include trunk, roots, branches, and leaves. Kinds of trees include deciduous and evergreen. And each of those parts and kinds can be further broken down into parts and kinds. The third observation is that people tend to store a new concept under a broader, more inclusive concept in their cognitive structures. The broader concept provides what Ausubel (1968) referred to as "cognitive scaffolding," and the process of learning that proceeds from broader, more inclusive and general concepts to narrower, more detailed concepts he called "progressive differentiation" because it entails a process of making progressively finer distinctions.

The kind of relationship upon which the conceptual elaboration sequence is based is one of inclusivity among concepts, with respect to either parts or kinds. Figure 3.9 on the next page shows kinds of music. The inclusivity relationships are generally referred to as superordinate, coordinate, and subordinate relationships. In Figure 3.9 classical music is subordinate to music, coordinate to medieval music, and superordinate to instrumental classical music. As you go further down in the conceptual structure to kinds of kinds of kinds (or parts of parts of parts), the concepts become progressively narrower and more detailed. David Ausubel (1968) postulated that concepts are organized in our heads in this manner, so more stable cognitive structures are formed if you learn a broader, more inclusive concept before its subordinate concepts. Schema theory (R.C. Anderson, 1984; Rummelhart & Ortony, 1977) supports this notion, but with additional complexity.

Therefore, the conceptual elaboration sequence is one that starts by teaching the broadest, most inclusive and general concepts that the learner has not yet learned, and proceeds to ever more narrow, less inclusive, and more detailed concepts until the necessary level of detail has been reached. You identify all these concepts and their inclusivity relationships by conducting a **conceptual analysis**. The result of such an analysis is a conceptual knowledge structure (see Figure 3.9), which is often referred to as a taxonomy. The term hierarchy is sometimes used, also, but this term miscommunicates because of the very different, more broadly accepted use of "hierarchy" to refer to a learning hierarchy.

It is worth noting that the lower concepts in a conceptual structure are not necessarily more complex or more difficult to learn. For example, children usually learn what a dog is long before they learn what a mammal is.

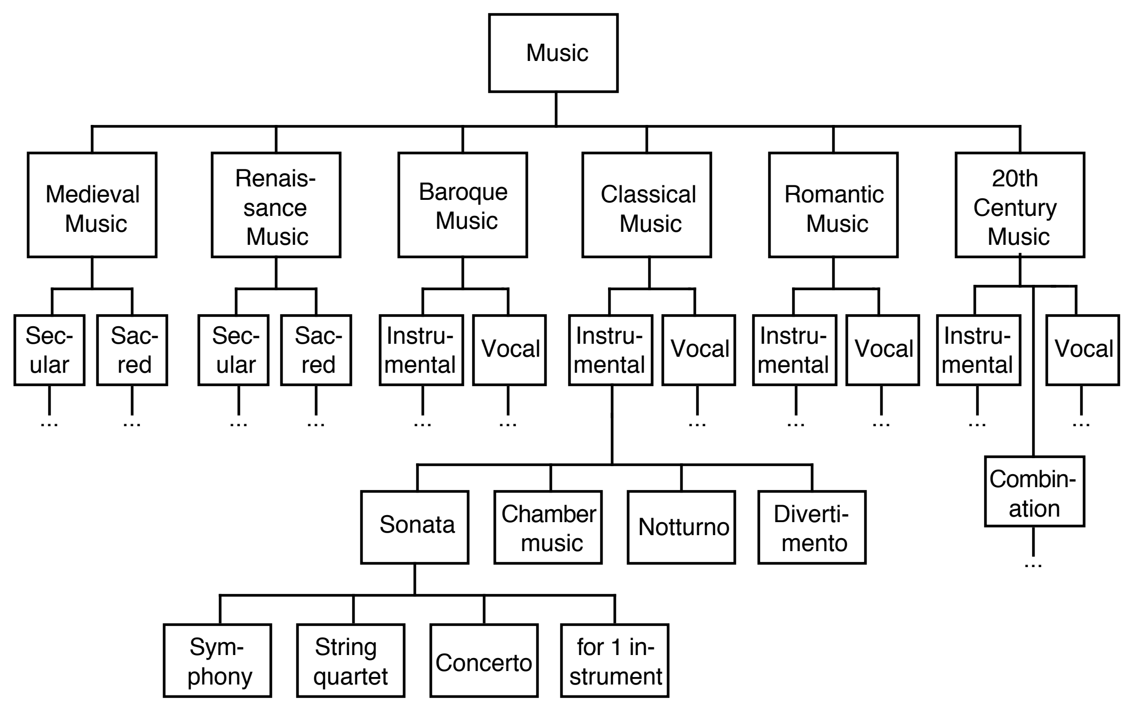


Figure 3.9 An example of a conceptual structure

It is worth noting a few conventions that help you to read and create conceptual structures such as that shown in Figure 3.9. First, the label for a concept is often an adjective that modifies the label of its superordinate concept. Sometimes the superordinate label is included, as with "Classical music," but most of the time it isn't (to save time and space), as with "Instrumental classical music" (see Figure 3.9). And then again, sometimes the label is completely different, as with "Sonata." Second, coordinate concepts may not always be aligned with each other, again due to space limitations, as with the three kinds of 20th century music. The three are on the same level of the conceptual structure, even though they may not line up right, as in Figure 3.9. Third, when the complete structure doesn't fit on a single page, you may want to use number codes to help a reader know where each break-down of concepts continues.

The **conceptual elaboration sequence** may be designed in either a topical or spiral manner. For a topical sequence, one could go all the way down one leg of the conceptual structure, and gradually broaden out from there. For a spiral sequence, one could go completely across the top row, then across the next row down, and so forth.

One point worth emphasizing is that the conceptual elaboration sequence doesn't violate the notion of learning prerequisites (hierarchical sequencing). To understand this, it helps to understand the nature of concepts. Concepts can have criterial definitions or functional definitions or "fuzzy" definitions. **Criterial definitions** are made up of qualities that the concept instances all have in common. Those qualities are referred to as common characteristics (such as "woody stem" for the concept "tree"). However, for teaching the skill of concept classification, we only care about the minimum set of common characteristics that learners need to distinguish members of the concept from members of other concepts. These are called the *critical characteristics*. (Of course, if our goal is fostering an understanding of a concept, then we have much broader interests.)

Functional definitions, on the other hand, are made up of functions or purposes. For example, electrical resistors cannot be defined by common characteristics because composition resistors have completely different characteristics from wire-wound resistors. What they have in common is the function they serve: to slow down the passage of electrical current in a wire. *Critical functions* are the minimum set of functions required to define a concept. Some concepts can only be defined by a combination of characteristics and functions. For example, "chair" requires a functional definition (something to sit on), but it also requires a characteristic (having a back) to distinguish it from a stool.

Fuzzy definitions are for fuzzy concepts—that is, concepts that cannot be precisely defined—such as "love." There is not a clear set of characteristics or functions for defining the concept.

The **learning prerequisites** for a concept are all of its critical characteristics and/or critical functions. But, a concept always possesses all the critical characteristics and functions of all the concepts directly above it in a kinds conceptual structure.[3] Therefore, since a conceptual elaboration sequence always teaches the higher, more general concepts before the ones directly under it, this sequence never violates hierarchical sequencing. It can be viewed as a special case (or an elaboration, if you wish) of hierarchical sequencing. The same is true of all the elaboration and SCM sequences.

[3] It also has additional critical characteristics and/or functions to distinguish it from its coordinate concepts (those concepts which are subordinate to the same superordinate concept).

The Theoretical Elaboration Sequence

The theoretical elaboration sequence (Reigeluth, 1987) is the second of the two sequencing strategies currently offered by the Elaboration Theory for building domain expertise. As indicated earlier, it is intended for courses that focus on interrelated sets of principles, which are usually elaborations of each other. Examples include a high-school biology course that focuses on principles of genetics, life cycles, and bodily functions, and a corporate training program on how and why a piece of equipment works. This sequencing methodology was derived primarily from Bruner’s (1960) spiral curriculum and Ausubel's advance organizers and progressive differentiation, but it differs in several important ways from each, and it also provides greater guidance as to how to design it. The sequence starts with the broadest, most inclusive, most general principles (which are also the simplest and generally the first to have been discovered), such as the law of supply and demand in economics and Ohm's law in electricity. And it gradually progresses to more narrow, precise, complex principles, such as those which relate to maximizing profits on the supply side (e.g., marginal revenues equaling marginal costs) and those which relate to consumer preferences on the demand side of the law of supply and demand. Again, this pattern of sequencing can be done in either a topical or spiral fashion.

The theoretical elaboration sequence is based on several observations. The first is that principles are either causal relationships or natural-process relationships among changes in concepts. For example, the law of supply and demand indicates how changes in the supply of, and demand for, something influence its price, and vice versa (how changes in its price influence its supply and demand). The second is that principles, like concepts, exist on a continuum from broader, more general, and more inclusive ones to narrower, more specific, and less inclusive ones. For example, according to Michael Kelly, a fairly general principle is:

- Temperature change in an environment causes behavioral changes in certain organisms within that environment.

And two subordinate principles are:

- High temperatures in a desert environment caused certain organisms to be nocturnal.
- High temperatures in a desert environment cause certain organisms to undergo a period of estivation.

And this last principle could be further elaborated by identifying specific physiological changes that occur in a particular species when it estivates (see Figure 3.10 on the next page for another example). So, unlike concepts, the broader principles are generally simpler and easier to learn than the narrower ones. This quality led principles to be the focus of Bruner’s (1960) “spiral curriculum.” The third observation is that, as with concepts, people tend to store a new principle under a broader, more inclusive one in their cognitive structures. Again, Ausubel (1968) discovered that the broader principle provides "cognitive scaffolding" for the narrower, more complex principles, and therefore recommended the general-to-detailed sequencing strategy he called "progressive differentiation". But there is a fourth observation for principles that does not hold for concepts. Principles can be combined into causal models that reflect the complex, systemic, and often seemingly chaotic nature of most phenomena in the world (see Figure 3.7 above).

The kind of relationship upon which the theoretical elaboration sequence is based is one of the complexity with which a given causal phenomenon is characterized. The more complex treatments (principles) are generally referred to as subordinate to the less complex ones. Therefore, the theoretical relationships are superordinate, coordinate, and subordinate, somewhat similar to conceptual relationships. For example, in Figure 3.10, principles 1 and 2 elaborate on principle 0 because they each provide more detail about what happens when light rays pass from one optical medium into another of different optical density.

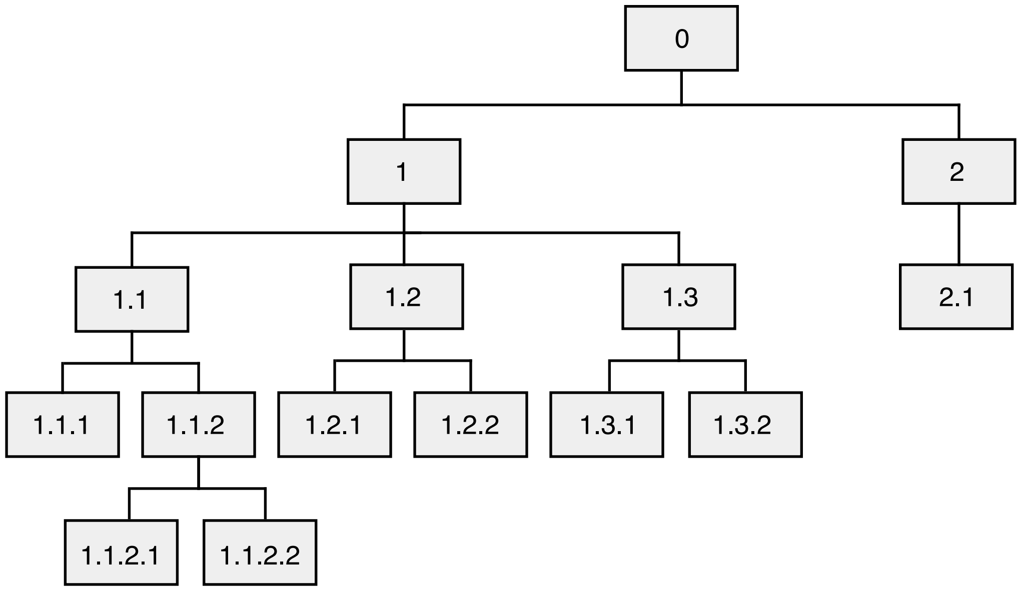
But how does a teacher or designer identify all these principles and their inclusivity/complexity relationships? This is the purpose of a **theoretical analysis**. The result of such an analysis is a theoretical structure (such as that shown in Figure 3.10), which is different from a causal model (Figure 3.7) in that it shows principles which elaborate on other principles (provide more complexity and/or guidance on the same phenomena), whereas a causal model shows principles that combine with other principles (add new phenomena), usually at a similar level of complexity.

It should be noted that more detail can be provided in a theoretical structure by elaborating on either the causal factors or the resultant factors (effects), or both. And elaboration can occur by answering several different kinds of questions, such as:

- What else happens? or What else can cause this?
- When does this cause have this effect?
- Which way (direction) do things change?
- Why do they change?
- How much do they change? (See Figure 3.10.)

The theoretical elaboration sequence starts by teaching the broadest, most inclusive, most general principles that the learner has not yet learned. And this sequence gradually proceeds to ever more narrow, less inclusive, more detailed, more precise principles until the desired level of complexity has been reached. The fact that this order reflects the order in which the principles were usually discovered—and could be most easily discovered by learners—makes this sequence ideal for problem-based learning and other discovery approaches.

When light rays pass from one medium into another (of different optical density):



0 they behave unexpectedly.

1 they bend at the surface,
2 a straight object in both media looks bent at the surface.

1.1 the rays bend because they slow down in a denser medium or speed up in a less dense medium (C),
1.2 rays bend and change their distance from each other but remain parallel to teach other (A),
1.3 a portion of each ray is reflected off the surface, while the rest is refracted into the new medium (A),
2.1 the apparent position and size of an object usually change (A).

1.1.1 if they pass into a denser medium, the light rays bend toward the normal (B,D),
1.1.2 the greater the difference in optical density between two media, the more the light rays bend (D),
1.2.1 when rays bend toward the normal, they become farther apart (B,D),
1.2.2 the sharper the angle between a light ray and the surface, the more the ray bends (D),
1.3.1 the sharper the angle between a light ray and the surface, the more of each ray that is reflected and the less that is refracted (D),
1.3.2 if the angle is equal to, or sharper than, the critical angle, all of the light ray is reflected (B,E).

1.1.2.1 the index of refraction (n) $= c_i/c_r = (\sin i)/(\sin r)$ (D,E),
1.1.2.2 the relationship between the critical angle and the index of refraction is: $\sin i_c = 1/n$ (D,E).

Codes:
(A) What else happens? (B) When? (B) Why? (C) Which way? (D) How much?

Figure 3.10. An example of a theoretical structure

The theoretical elaboration sequence may also be done in either a topical or spiral manner. For a topical sequence, one could go all the way down one leg of the theoretical structure, and gradually broaden out from there. For a spiral sequence, one could go completely across the top row, then across the next row down, and so forth.

When and Why to Use It?

In both training and education contexts much instruction focuses on complex cognitive tasks. The strengths of the SCM sequence for such tasks are:

- It enables learners to understand complex tasks holistically by acquiring the skills of an expert for a real-world version of the task from the very first module of the course.
- These in turn enhance the motivation of learners and, therefore, the quality (effectiveness and efficiency) of the instruction.
- The holistic understanding of the task also results in the formation of a stable cognitive schema to which more complex capabilities and understandings can be assimilated. This is especially valuable for learning a complex cognitive task.
- Since the learners start with a real version of the task from the beginning, the SCM is ideally suited to situated learning, problem-based learning, computer-based simulations, and on-the-job training.
- The SCM can be used with highly directive instruction, highly constructivist instruction, or anything in between.

The strengths of the conceptual and theoretical elaboration sequences are:

- They help to build the cognitive scaffolding (schemata) that makes subsequent, more complex understandings much easier to attain and retain.
- The enhancement of understanding aids motivation.
- These sequences can be used in either directive or constructivist approaches to instruction.

The limitations of the SCM and elaboration sequences are:

- The content (task or domain expertise) must be fairly complex and large to make the approach worthwhile. With smaller amounts of content, these approaches won't make much difference in the quality of the instruction.
- The SCM sequences must be used with other sequencing strategies that provide guidance for within-module sequencing. For example, procedural tasks require a combination of procedural and hierarchical approaches for within-module sequencing. Actually, as an instructional theory that synthesizes existing knowledge about sequencing, the elaboration theory includes guidelines for using those other approaches with the SCM approaches.

The net effect is that the SCM and elaboration sequences are powerful methods for complex tasks and domains, but they are a bit more complex and hence more difficult to learn, though not much more difficult to use once they are learned.

Furthermore, the SCM task analysis procedures and the elaboration sequence content analysis procedures are both very efficient (see Chapter 6). Because these procedures allow task/content analysis and sequence design to be done simultaneously, it is possible to do *rapid prototyping* so that the first module can be designed and developed before any task or content analysis is done for the remaining modules of the course or curriculum. A rapid prototype can provide a good sample for inspection and approval by clients, higher management, and other stakeholders (Box 3.5 on p. 2), as well as for formative evaluation and revision of the prototype (Box 3.3), that can strongly improve the design of the remaining modules.

Other Sequences

The four types of elaboration sequences just described are each based on a single type of relationship within the content, and there are likely additional elaboration sequences that fit the basic principles of epitomizing and elaborating described earlier, as well as many sequences that don't (such as the historical sequence, which is based on the chronological relationship among events). But even more important is the utility of thinking about sequencing strategies for different types of courses, in addition to ones for different types of relationships. Often, such strategies will be combinations of ones based on relationships, but not always.

The following are some of the types of common courses we have identified that seem likely to benefit from different types of course sequences, but there are surely many more that need to be identified:

- history courses, such as European History, or courses on the history of a particular field or discipline, such as physical therapy or economics,
- courses on the theory and practice of a particular field, such as physical therapy or electronics,
- appreciation courses, such as music appreciation or art appreciation,
- philosophy courses, such as the philosophy of education,
- science courses, such as biology and physics,
- skill courses, such as algebra, English composition, or electronic troubleshooting.

It is beyond the scope of this book to explore differences in sequencing strategies for these common types of courses, partly because we have been unable to find much work on them. Nevertheless, we do discuss sequencing strategies for two such types of courses, to illustrate the kinds of strategies that need to be further researched and developed.

History Courses

by William R. Jones & Charles M. Reigeluth

Perhaps the two most common kinds of history courses are (a) the history of a geographical area during a certain period, such as the history of the Roman Empire, and (b) the history of a field (or discipline), which is concerned with the historical development of knowledge in the field and often with the major organizations that exist, the major people who have contributed to the field, the major issues of concern today, and so forth. For both of these kinds of history courses, It is far from certain what kind of sequence will best serve student learning and motivation, and in many cases sequencing may not make much of a difference in the quality of the instruction. But teaching the historical events in the order in which they occurred is likely to be beneficial, with several qualifications or variations.

To understand these variations, it is important to recognize that there are often different themes, issues, or areas of knowledge that change or develop over time. We refer to these as thematic areas. Their existence makes two major sequencing options possible. In one, the instruction presents each thematic area as a cohesive unit, following its development chronologically from beginning to end before moving on to the next thematic area. In the other, the instruction follows the chronology from beginning to end, covering all thematic areas in a particular time period, with the instructor revisiting each theme during successive time periods.

Each of these two options has its weakness. The first cuts each thematic area off from other themes and from the historical context in which it developed. The second arbitrarily breaks a thematic area up into sequential parts that are difficult to reconnect into a memorable story because of all the other themes that are studied before returning to it.

These options bear some resemblance to the topical and spiral sequences, respectively (see Chapter 2). And these, too, can be viewed as being on a continuum by adjusting the length of the periods and the extent to which other thematic areas are discussed when dealing with a given area. A successful strategy would probably combine elements of both these options, and certainly each topic has its own unique characteristics that will suggest a certain combination of these two options for teaching it.

Historical Thinking

To avoid an excess of trial-and-error in finding that combination, an investigation into the nature of historical thinking might help to suggest some useful paths. Consider the following propositions:

Historians achieve mastery of a topic area through repetitive study.

No historian responsible for teaching an American history survey course, for example, teaches from a perfect memory of the American history survey that he or she took as an undergraduate. Rather, the original survey was supplemented by upper-level courses on special topics, then by graduate study on other special topics, and on and on. By the time a professional historian begins teaching in the classroom, it is quite possible for him or her to recall at will complex narratives that frustrate the efforts of undergraduates to do the same. The reason for this is not that historians are better at remembering than other people, but that they have revisited many stories at progressively greater levels of sophistication (or elaboration) over a period of time until they have become expert at remembering and relating them.

Historians use scaffolding to reason about history.

Before the new social history of the 1960s began to spread its influence, it was very popular to teach U.S. history as a history of its Presidents and, more importantly, to define the national mood through the character of the person sitting in the Oval Office. Hence, all Americans in the 1820s were rugged individualists like Andrew Jackson. This mode of history teaching was replaced by the periodization of American history that is still quite popular. Here the march of history is divided into the Gilded Age, the Progressive Era, the Jazz Age, the Depression, the 1950s, and so on. But historians are no happier with this because, while these categories are easy to remember, they are too simplistic to describe what really happened in the past. And yet, every historian uses scaffolding of this type to make quick judgements about historical information with which they come into contact. Such scaffolding is good as long as it is only used as a tool that does not obscure historical detail.

Historians remember stories, not facts.

The history student who attempts to memorize long lists of names, dates, and events without understanding the story underneath inevitably fails. The historian, by comparison, does not memorize facts but instead memorizes stories. Stories are easy to remember because they have literary qualities. The suspense of an unknown outcome, the drama of unique human personalities interacting on a public stage, these elements of historical storytelling combine to create an affective mnemonic device that aids mastery of a topic.

Guidelines

With these propositions in mind, we can offer some related guidelines for sequencing instruction on historical topics:

1) Make the lesson plan iterative. This approach draws on the Elaboration Theory. Give an overview of the entire course, describing the broad progression of thematic areas that the instruction will cover. The objective is to give students a framework in which to place the in-depth course modules that will follow, regardless of the extent to which they are organized around periods vresus themes. Revisit the broad picture of the course often enough so that the students can rework in their minds the interplay of themes and periods.

2) Make use of scaffolding to aid reasoning. In the broad presentation of the course material, introduce the thematic areas and periodizations that aid in understanding the material. In the in-depth modules describe the complexity that underlies the scaffolding. This way the students can continue to use the scaffolding as a tool for thinking, but will not be restricted by its inherent simplicities.

3) Choose thematic strands that can stand alone as stories. [This either needs to be elaborated or deleted.]

Courses on the history of a field frequently differ from other history courses in a way that may have important implications for sequencing. A typical focus for such courses is to compare and contrast each historical development with the current state of knowledge in the same area, as well as with earlier developments. Comparing and contrasting with earlier developments entails tracing "threads" of knowledge (which are like themes) as they developed over time, as well as showing how those threads are woven together in the tapestry of the field (or discipline), just as you would with themes in other kinds of history courses.

But comparing and contrasting each historical development with the current state of knowledge has different implications for a course sequence. Perhaps the course should begin with the current state of knowledge, or at least review it if the students already possess that kind of knowledge upon entering the course. Also, perhaps the sequence should place greater emphasis on tracing the complete historical development of a single thread, and then going back to trace the development of another and another until all threads have been traced, and place less emphasis on trying to deal with all threads at once. If this is done, then extra care should be taken to highlight interlinkages with other threads as the course progresses.

If knowledge about organizations, people, issues, and so forth are included in the course, then those topics may be best taught as separate threads within this sequencing pattern. A major question that remains is the order in which the different threads should be taught. Our inclination is to teach them in the order of their importance to understanding the nature of the field (or discipline).

These are but a few of the many additional sequences you might want to use. For more information about these and other sequences, see Posner and Strike (1976), ...

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Theory and Practice Courses

A course on the theory and practice of a field is concerned with both task expertise (how an expert practitioner pursues different goals) and domain expertise (what descriptive theories underlie the techniques and strategies that experts use). Therefore, one sequencing strategy that has some promise is a combination of a theoretical elaboration and an SCM sequence. The SCM sequence (for any combination of procedural and heuristic elements) begins with the simplest representative version of the task, and the theoretical epitome is designed to provide the underlying descriptive theory that applies to only that simple set of conditions.

[Include some of the Beissner work here.]

What's Next?

Given this general understanding of the hierarchical, procedural, SCM, and elaboration sequencing strategies, the next four chapters provide detailed guidance on how to design each of these four types of sequences. Examples and practice exercises are also provided.

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