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A New Paradigm of Instructional Theory

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18 The Elaboration Theory: Guidance for Scope and Sequence Decisions

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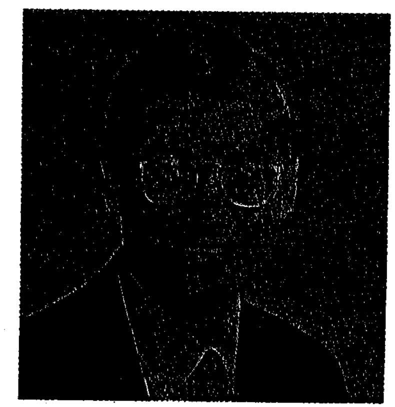

Charles M. Reigeluth

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FOREWORD

Goals and preconditions. *The primary goal of this theory is to help select and sequence content in a way that will optimize attainment of learning goals. It is intended for medium to complex kinds of cognitive and psychomotor learning, but does not currently deal with content that is primarily in the affective domain.*

Values. *Some of the values upon which this theory is based include:*

- *a sequence that is as holistic as possible, to foster meaning-making and motivation,*
- *allowing learners to make many scope and sequence decisions on their own, during the learning process,*
- *an approach that facilitates rapid prototyping in the instructional development process,*
- *the integration of viable approaches to scope and sequence into a coherent design theory.*

Methods. *Here are the major methods this theory offers:*

1. *Conceptual elaboration sequence*
   - *Use this approach when the goals call for learning many related concepts.*
   - *Teach broader, more inclusive concepts before the narrower, more detailed concepts that elaborate upon them.*
   - *Use either a topical or a spiral approach to this conceptual elaboration.*
   - *Teach "supporting" content (principles, procedures, information, higher-order thinking skills, attitudes, etc.) together with the concepts to which they are most closely related.*
   - *Group concepts and their supporting content into "learning episodes" that aren't so large as to make review and synthesis difficult but aren't so small as to break up the flow of the learning process.*
   - *Give students some choice as to which concepts to elaborate upon first/next.*
2. *Theoretical elaboration sequence*
   - *Use this approach when the goals call for learning many related principles.*
   - *Teach broader, more inclusive principles before the narrower, more detailed ones that elaborate upon them.*
   - *Use either a topical or a spiral approach to this theoretical elaboration.*
   - *Teach "supporting" content (concepts, procedures, information, higher-order thinking skills, attitudes, etc.) together with the principles to which they are most closely related.*
   - *Group principles and their supporting content into "learning episodes."*
   - *Give students some choice as to which principles to elaborate upon first/next.*

3. *Simplifying conditions sequence*
   - *Use this approach when the goals call for learning a task of at least moderate complexity.*
   - *Teach a simpler version of a task (that is still fairly representative of all versions) before teaching progressively more complex versions.*
   - *Use either a topical or a spiral approach to this simplifying conditions sequence.*
   - *For procedural tasks focus on teaching steps; for heuristic tasks focus on teaching principles; and for combination tasks teach both steps and principles—in accordance with the way experts think about the task.*
   - *Teach "supporting" content together with the steps and/or principles to which they are most closely related.*
   - *Group steps/principles and their supporting content into "learning episodes."*
   - *Give students some choice as to which versions of the task to learn next.*

Major contributions. *Detailed guidance for designing holistic sequences for several kinds of course content. Guidance for scope and sequence decisions for heuristic tasks, including heuristic task analysis methods.*

—C.M.R.

The Elaboration Theory: Guidance for Scope and Sequence Decisions

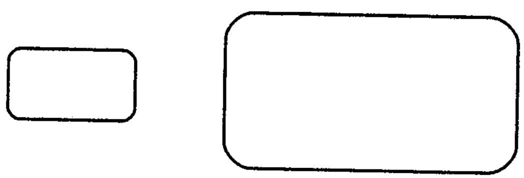
The paradigm shift from teacher-centered and content-centered instruction to learner-centered instruction is creating new needs for ways to sequence instruction. In the industrial-age paradigm the need was to break the content or task down into little pieces and teach those pieces one at a time. But most of the new approaches to instruction, including simulations, apprenticeships, goal-based scenarios, problem-based learning, and other kinds of situated learning, require a more holistic approach to sequencing, one that can simplify the content or task, not by breaking it into pieces, but by identifying simpler real-world versions of the task or content domain. The elaboration theory was developed to provide such a holistic approach to sequencing that also makes the learning process more meaningful and motivational to learners. And it was developed to provide an approach that allows instructional designers (including teachers) to empower learners to make some scope and sequence decisions during the learning process.*

In this chapter I begin by discussing some basics about sequencing and when it is beneficial to use the elaboration theory. Then I discuss each of the different kinds of elaboration sequences, with particular emphasis on the simplifying conditions method.

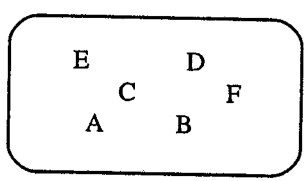
What Do Sequencing Strategies Entail?

Decisions about sequencing are concerned with how to group and order the content. You cannot order the content without creating some kind of groupings to be ordered, and different kinds of sequences require different kinds of groupings. Therefore, decisions must be made about what content should be in each grouping. This is why educators often talk about "scope and sequence" together.** *Scope* is concerned with what to teach: the nature of the content.[1] It requires decisions about what the learner needs and/or wants to learn. Scope and sequence decisions involve several types of decisions regarding:

- the size of each group of content (learning episode):

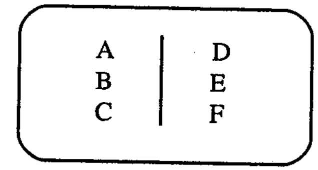


- the components of each learning episode:

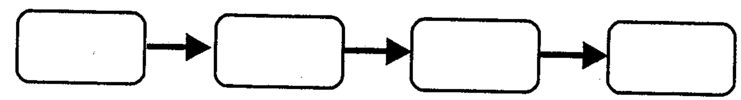


* Which common features of the new paradigm do you recognize here?
** Again we see the integration of curriculum theory and instructional theory.
[1]I use the term "content" to refer to everything that comes under "what to teach." It therefore includes whatever tasks you might teach as well as whatever knowledge, and the term "content analysis" includes "task analysis." It also includes generic skills and attitudes.

- the order of components within each episode:



- and the order of episodes:



all of which influence the quality of the learning experience: its effectiveness, efficiency, and appeal.

Does Scope Make a Difference?

If you are in a training department for any of the three sectors (private, public, or nonprofit), the employees or customers need certain skills and knowledge to perform well. If you don't teach what they need, it doesn't matter how good the remaining aspects of the instruction are.

However, a K–12 or higher education context is very different, in that needs are much less clear and depend largely on values. Furthermore, students have interests that may be unrelated to the values that the community and the parents hold. And the benefits of the instruction may not become apparent until many years later. All these factors make it much more difficult to say whether scope makes a difference, or perhaps more accurately, what kinds of difference scope makes. Clearly, the differences made by scope will vary from one student to another and from one "stakeholder" to another in the educational system. (Stakeholders are all those who have a stake in the particular educational system, such as parents, employers, taxpayers, students, social service agencies, and so forth.) But ask any student or any stakeholder whether "what is taught" makes a difference to them, and you are almost certain to hear a resounding "Yes!"

General Concerns for Deciding on Scope

If scope does make a difference, how can you make sure that you select the right content?

Training Contexts. For training contexts, the answer is fairly straightforward. You conduct a needs analysis. Much has been written elsewhere about how to conduct a needs analysis (see, e.g., Kaufman & English, 1979; Kaufman, Rojas, & Mayer, 1993; Rossett, 1987). But I would also like to suggest that the selection of goals for an organization to pursue be based as much on values as it is on needs. Issues relating to the quality of products and the ways in which customers will be treated are two cases in point that could have powerful influences over what to teach. More attention should be placed on values analysis in the instructional design process.

Education Contexts. For K–12 and higher education contexts, it is more difficult to make sure that you select the right content, for all the reasons outlined earlier:

- needs are much less clear,
- needs depend largely on values,
- students have interests of their own, and
- benefits may not become apparent until many years later.

Furthermore, just as the business world has been evolving from standardization to customization, perhaps the content-selection process for the K–12 and higher education contexts should not require that students learn all the same things. Osin and Lesgold (1997) talk about "defining a required common curriculum and supporting additional student choices" (p. 642). Technology is evolving to the point where we can create flexible, computer-based learning tools that students can use—while they are learning—to create or modify their own instruction.* Therefore, much of the content selection that is now done by a teacher (or curriculum committee) for a whole "batch" of learners well ahead of the actual instruction could soon be done during the instruction as the multimedia systems and the teacher continuously collect information from individual learners and/or small teams of learners and use that information to present an array of sound alternatives to the learner(s),[2] about both what to learn next and how to learn it. This will require designing scope and sequence options in ways that are fundamentally different from the ways scope and sequence decisions have been made in the past.

Does Sequencing Make a Difference?

This is a very common type of question to ask, but it is the wrong type! The issue, as with most instructional strategies, is not whether it makes a difference, but when it makes a difference. The impact of sequencing depends upon two major factors: the strength of relationships among the topics and the size of the course of instruction.

*See e.g., chapter 17 by Merrill.

[2]These systems and the teacher can also provide guidance to the learner after she or he chooses from an unlimited set of alternatives.

Sequencing is only important when there is a strong *relationship among the topics* of the course. If a course is composed of several unrelated topics, such as word processing, computer graphics, and electronic spreadsheets, the order for teaching the topics is not likely to make much difference. On the other hand, when there is a strong relationship, the sequence will influence how well both the relationship and the content are learned. For example, there is an important relationship between the analysis and design phases in the instructional systems development (ISD) process. Some sequences take a fragmented approach that makes it difficult to learn the relationship and understand the content, whereas other sequences facilitate such learning by dealing with both phases simultaneously or spiraling frequently from one to the other.

Second, if there is a strong relationship among the topics, then, as the *size of the course* increases, so does the importance of sequencing. When the content requires more than a couple of hours to learn, sequencing is likely to begin to make a significant difference in the learners' ability to master it, because most learners will have a difficult time organizing so much content logically and meaningfully if it is poorly sequenced. However, when the content to be learned is minimal (e.g., less than a couple of hours), the human mind can compensate for weaknesses in the sequence.*

Types of Sequencing Strategies

Relationships Are the Key. The importance of relationships is twofold. First, as was just mentioned, if no relationships exist, then sequencing doesn't matter. But, second, each method of sequencing is based upon a *single type of relationship*. For instance, a historical sequence is based upon the chronological relationship—a sequence is devised that follows the actual sequence of events. A procedural sequence, the most common pattern of sequencing in training, is based upon the relationship of "order of performance" of the steps in the procedure. A hierarchical sequence is based upon the relationship of learning prerequisites among the various skills and subskills that comprise a task. And the "simplifying conditions" sequence (described later) is based upon the relationship of the degree of complexity of different versions of a complex task.**

Furthermore, when a number of topics needs to be taught, two basic patterns of sequencing can be used that are fundamentally different: topical and spiral (see Fig. 18.1).

Topical Sequencing. In topical sequencing, a topic (or task) is taught to whatever depth of understanding (or competence) is required, before moving to the next one. There are both advantages and disadvantages of topical sequencing.

* Did you recognize these two paragraphs as identifying two preconditions for all theories or methods of sequencing, not just the elaboration theory?

** Is this design theory or descriptive theory?

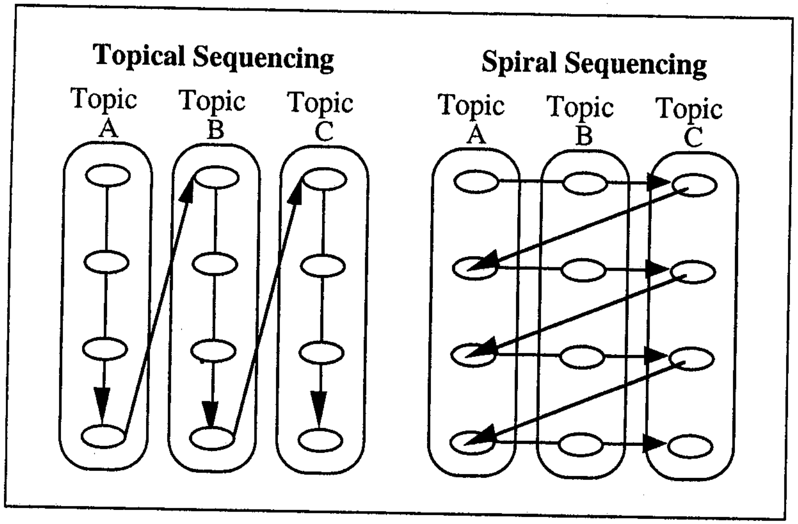


FIG. 18.1. Topical and spiral sequencing. (From Reigeluth & Kim, 1993)

Learners can concentrate on one topic (or task) for in-depth learning without frequently skipping to new ones. And hands-on materials and other resources are all used in one block of time, rather than being used at different points scattered over several months or a year. However, once the class (or team or individual) moves on to a new topic (or task), the first one is often forgotten. And the learners don't gain a perception of what the whole subject domain is like until they reach the end of the course (or curriculum). The weaknesses of topical sequencing can be compensated for, to some extent, by incorporating instructional tactics for overview, review, and synthesis.*

Spiral Sequencing. In spiral sequencing (Bruner, 1960), the learners master a topic (or task) gradually in several passes. The learner learns the basics of one topic (or task), then another, and another, and so on, before she or he returns to learn more about each topic, and this pattern continues until the necessary depth and breadth are reached for all of them. The main advantage of spiral sequencing is its built-in synthesis and review. The interrelationships among topics (or tasks) may be learned more easily using the spiral approach because it allows similar aspects of the various topics (or tasks) to be learned close in time to each other. Furthermore, cycling back to learn more about an earlier topic (or task) provides a periodic review of the earlier one. On the other hand, the main disadvantage of spiral sequencing is disruption. To frequently switch topics disrupts the learners' thought development, as well as the efficient management of material resources.

* Two issues were touched on here. To what extent do you think *all* methods of instruction have both strengths and weaknesses? And to what extent can a method that has a certain weakness be complemented with a method that compensates to some extent for that weakness?

Which one Is best? Again, this is a very common type of question, but the wrong type! The issue is not which pattern of sequencing is best, but when each is best. Furthermore, in reality, neither topical nor spiral sequencing exists in a pure form. In an extreme case, spiral sequencing could entail presenting only one sentence on each topic (or task) before moving on to the next. The real issue lies in how deep or broad a slice a teacher or learner makes into one topic before going on to another. Rather than thinking of spiral and topical sequencing as two separate categories, it is useful to think of them as the two endpoints on a continuum. The instructional designer's (or the learner's) decision, then, is where on the continuum to place any given training program or curriculum (or when to select any given point on the continuum).*

When to Use the Elaboration Theory and Why

In both training and education contexts, much instruction focuses on complex cognitive tasks (with a focus on skills) and/or cognitive structures (with a focus on understanding).

Regarding complex tasks, the simplifying conditions method (SCM) sequencing strategy enables learners to understand the tasks holistically and to acquire the skills of an expert for a real-world task from the very first lesson (or module, or segment, etc.; I prefer Bruner's term, "learning episode," because it has a more holistic, less fragmented connotation). These skills enhance the motivation of learners and, therefore, enhance the quality (effectiveness and efficiency) of the instruction. The holistic understanding of a task 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. Also, since the learners start with a real version of the task from the beginning, this method is ideally suited to situated learning, problem-based learning, computer-based simulations, and on-the-job training. Further, it can be used with highly directive instruction, highly constructivist instruction, or anything in between.

Regarding cognitive structures (understanding), the elaboration sequences help to build the cognitive scaffolding that makes subsequent, more complex understandings much easier to attain, through either directive or constructivist approaches to instruction. Therefore, this sequencing strategy also results in the formation of stable cognitive schemata to which more complex understandings are more easily added.

* Did you notice that *two* ways of transcending "either-or" thinking were offered here?

The limitations of the SCM and elaboration sequences are:

- The content 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-episode sequencing. For example, procedural tasks require a combination of procedural and hierarchical approaches for within-episode sequencing. However, as an instructional theory that synthesizes existing knowledge about sequencing, the elaboration theory includes guidelines for using those other approaches with the SCM approach.

The net effect is that the SCM and elaboration sequences are powerful methods for complex content, but they are a bit more complex and hence more difficult to learn to design, though perhaps actually easier to design than alternatives once they are learned.

Furthermore, the SCM task-analysis procedures and the elaboration sequence content-analysis procedures are both very efficient. 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 learning episode can be designed and developed before any task or content analysis is done for the remaining episodes of the course or curriculum. A rapid prototype can provide a good sample for inspection and approval by clients, higher management, and other stakeholders, as well as for formative evaluation and revision of the prototype, which can strongly improve the design of the remaining episodes.

WHAT IS AN ELABORATION SEQUENCE?

The elaboration theory of instruction was developed to provide a holistic alternative 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.[3] 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. *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 quite the same as the distinction between procedural and declarative knowledge (J. R. Anderson, 1983).

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 and psychomotor 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. Consequently, the elaboration theory offers the SCM to design a holistic, simple-to-complex sequence by starting with the simplest real-world version of the task and gradually progressing to evermore complex versions as each is mastered. For example, solving mathematical problems is easier when you are solving for one unknown than when there are two unknowns. The number of unknowns is a condition variable having two conditions: one unknown and two 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 Vygotsky (1978) called "the zone of proximal development"—close enough to the learner's present competence for the learner to be able to deal with successfully—and they should gradually increase in complexity.

But not all complex tasks are of the same nature. Some are primarily procedural (i.e., tasks for which experts use a set of steps, mental and/or physical, 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), and some are primarily heuristic (i.e., tasks 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). Most tasks, however, 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 is a bit different for the procedural than for the heuristic elements of a task, because what must be learned (the content) is different, and the relationships within that content are different. The SCM is discussed in more detail later.

Before we proceed to a discussion of domain expertise, it may be helpful to clarify what I mean by a causal model, for it is important in upcoming discussions. A causal model is an interrelated set of cause–effect relationships, in which there are

* In this sense, it represents a different paradigm of instructional sequencing.

[3]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 (see, e.g., Greenberg & Kusché, 1993) 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 jealously, pride, and guilt." (p. 278).

* Did you recognize this as a situationality?

chains of causes and effects and there are usually multiple causes of the effects and multiple effects of the causes (see Fig. 18.2). 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.

Fig. 18.2 shows 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."

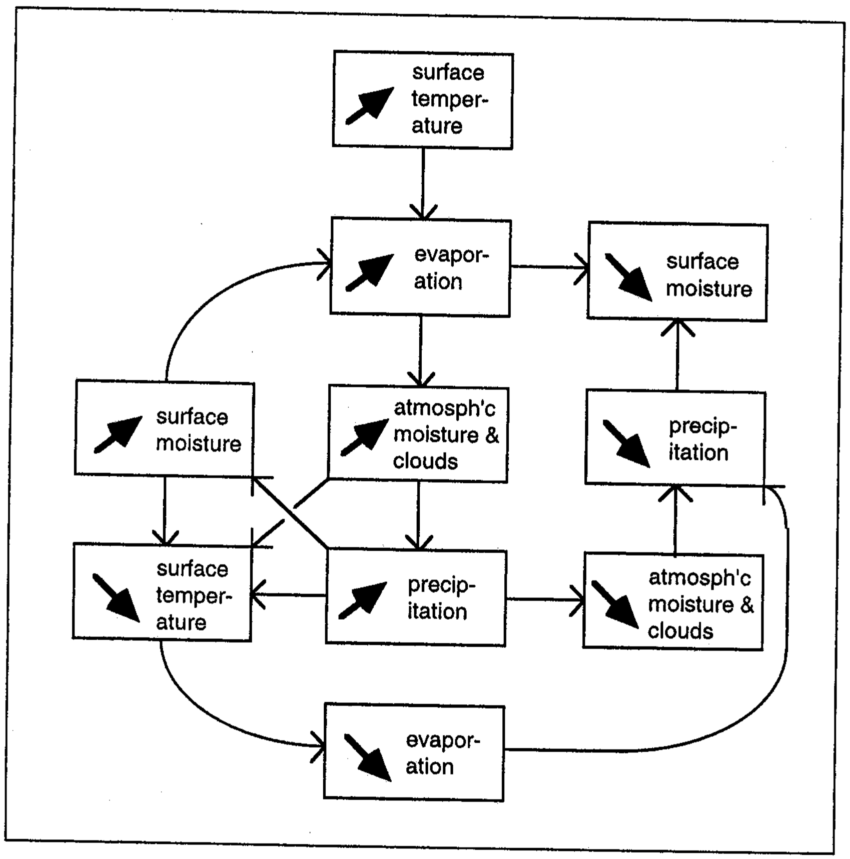


FIG. 18.2. A partial example of a causal model related to the water cycle.

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. An elaboration sequence starts with the broadest, most inclusive, most general ideas (which are also the simplest and generally among the first to have been discovered), such as the law of supply and demand in economics and Ohm's law in electricity. It gradually progresses to more complex, precise ideas, such as those that relate to maximizing profits on the supply side (marginal revenues and marginal costs) and 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.

But 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" (described later; see Fig. 18.4) 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. Consequently, the elaboration theory offers guidance for sequencing the development of 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 (knowledge structures) in a course. This is referred to as *multiple-strand sequencing* (Beissner & Reigeluth, 1994).

The conceptual elaboration sequence is described next, followed by the theoretical elaboration sequence and finally the SCM sequence.

The Conceptual Elaboration Sequence**

The conceptual elaboration sequence (Reigeluth & Darwazeh, 1982) 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

* Here, a situationality has required breaking a general method down into more detailed kinds, each of which is used for a different parameter of that situational variable.

** As more detail is provided about this method, try to decide if it is parts, kinds, or criteria, as discussed in chapter 1, p. 10. Also, try to differentiate descriptive theory from design theory.

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. Fig. 18.3 shows kinds of music. The inclusivity relationships are generally referred to as superordinate, coordinate, and subordinate relationships. In Fig. 18.3 classical music is subordinate to music, is coordinate to medieval music, and is 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. 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. Please note 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.

The conceptual elaboration sequence is one that starts by teaching (or discovering) 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. This kind of sequence might be used by a high school student interested in learning about the kinds and parts of animals and plants or by an employee interested in learning about the kinds and parts of equipment that the company sells. But how do you identify all these concepts and their inclusivity relationships? This is the purpose of a conceptual analysis. The result of such an analysis is a conceptual knowledge structure (see Fig. 18.3), 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 (Gagné, 1968).

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 lower row, and so forth.

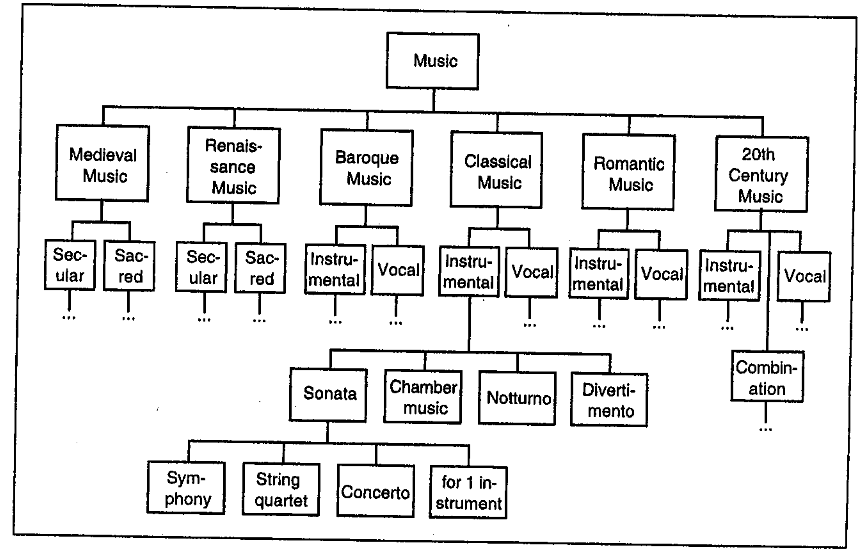


FIG. 18.3. An example of a conceptual structure.

One point worth emphasizing is that the conceptual elaboration sequence doesn't violate the notion of learning prerequisites (hierarchical sequencing) because concepts higher in a conceptual knowledge structure contain some of the prerequisites for concepts below them but no prerequisites for any concepts above them (Wilson & Merrill, 1980).

For more about the conceptual elaboration sequence, see Reigeluth (in press).

The Theoretical Elaboration Sequence

The theoretical elaboration sequence is the second of the two sequencing strategies currently offered by the elaboration theory for building domain expertise. It is intended for courses that focus on interrelated sets of principles, which are usually elaborations of each other, such as a high school biology course that focuses on principles of genetics, life cycles, and bodily functions, or a corporate training program on how and why a piece of equipment works (not how to use it).

This sequencing strategy 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[4], 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 cause certain organisms to be nocturnal.
- High temperatures in a desert environment cause certain organisms to undergo a period of estivation.

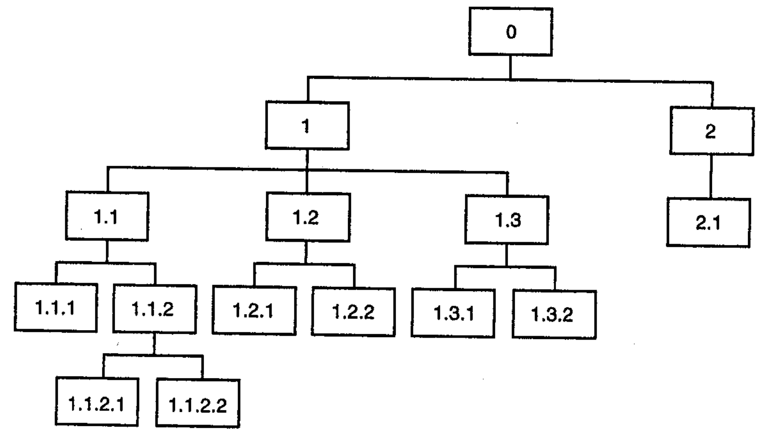
And this last principle could be further elaborated by identifying specific physiological changes that occur in a particular species when it estivates. Fig. 18.4 shows another example. So, unlike concepts, the broader principles are generally simpler and easier to learn than the narrower ones. This quality 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 Fig. 18.2).

The theoretical elaboration sequence starts by teaching the broadest, most inclusive, most general principles that the learner has not yet learned (which are also the simplest principles and generally the first to have been discovered); and it gradually progresses to ever more narrow, less inclusive, more detailed, more precise principles (which are also more complex and were generally discovered later). Examples were given earlier for economics (the law of supply and demand) and electricity (Ohm's law). This sequence continues 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.

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 (see Fig. 18.4), which is different from a causal model (Fig. 18.2) in that it shows principles that elaborate on other principles (which provide more complexity and/or guidance on the same phe-

[4]In an assignment for a graduate course at Syracuse University.

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?

FIG. 18.4. An example of a theoretical structure.

nomena), whereas a causal model shows principles that combine with other principles (add new phenomena), usually at a similar level of complexity.

You can see in Fig. 18.4 that 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 Fig. 18.4, 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.

It should be noted that more detail can be provided 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 Fig. 18.4.)

The theoretical elaboration sequence may also be done in either a topical or a 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.

For more about the theoretical elaboration sequence, see Reigeluth (1987; in press).

The Simplifying Conditions Method

For building task expertise, the SCM is a relatively new approach (though practitioners have long used it intuitively) that offers guidance for analyzing, selecting, and sequencing the "what to learn" (content). Briefly, SCM provides practical guidelines to make a very different kind of simple-to-complex sequence 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 teaches *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,

* Have you noticed that the processes described here for breaking concepts and principles down into more detailed ones represent a more general case of the process described in chapter 1 (p. 10) of breaking methods down into more detailed parts, kinds, and/or criteria?

real-world performances of the task. This process contrasts sharply with the hierarchical approach to sequencing, which teaches all the prerequisites first and does not teach a complete, real-world task until the end of the sequence. Fig. 18.5 shows the differences between the hierarchical approach and the SCM approach.

For *procedural tasks,* the focus is on the steps (mental and/or physical) that experts use to decide what to do when. The SCM's selection (scope) and sequencing

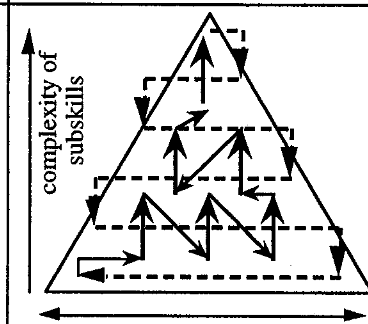
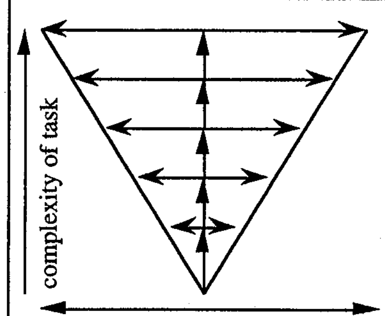
	Hierarchical Task Analysis and Sequencing	Task Analysis and Sequencing with SCM
Conceptual map	 diversity of subskills Hierarchical Analysis - - ► Hierarchical Sequencing ──►	 diversity of task Analysis and Sequencing with SCM ──►
underlying logic	Part to whole/Simple to Complex (Subskills to main skills)	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.		

FIG. 18.5. Hierarchical approach and the SCM approach. (From Reigeluth & Kim, 1993)

methodology was derived primarily from the work of Scandura (1973) and 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 other), and it also represents at least two different conditions of performance.

In contrast, for *heuristic tasks* (Reigeluth, 1992; Reigeluth & Kim, 1993), the focus is on principles, guidelines, and/or causal models that experts use to decide what to do when (rather than using a set of steps).* Such 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 do not think in terms of steps when they perform the task. This sequencing methodology was derived by Reigeluth primarily from the procedural SCM sequence.

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).

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 (but usually real-world) conditions, referred to as the *simplifying conditions.*

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 simplifying conditions are removed one by one to define each of the more complex versions of the task.

* This is a kind of learning that was not addressed much by the industrial-age paradigm of instructional theory but is receiving much attention in the new paradigm.

Since this is a relatively unknown approach to sequencing, some guidance for designing it is provided in the remainder of this chapter.

How to Design an SCM Sequence*

An SCM sequence is designed by integrating task analysis with design.** The analysis/design process centers around the questions, "What is the simplest version of the task that an expert has ever performed?" and "What is the next simplest version?" and so forth. As each version is identified, its place in the sequence is simultaneously determined.

In addition to this rule of thumb, you may find the following guidance helpful.*** Since designing an SCM sequence is more of a heuristic than a procedural process, the guidelines that follow include heuristics (bulleted) as well as steps (numbered), although, due to space limitations, I have not identified the full set of heuristics that an expert would use. Only the most important heuristics are included below. The procedural elements tend to predominate at the upper levels of analysis (the major phases of the task), but there comes a point at which it is no longer productive to break a given step into substeps, for that is not the way an expert thinks. Rather, you must identify the heuristics upon which an expert's performance of the step is based. I hope that the following portrayal will help to illustrate this nature of combination tasks.

Phase I. Prepare for Analysis and Design

1. Preparation. Lay the groundwork for your analysis and design.

1.1. Establish rapport with a SME (subject-matter expert).****
1.2. Identify the characteristics of the task in general.
1.3. Identify the characteristics of the learners in general.
1.4. Identify the delivery constraints (or fuzzy vision) of the instruction in general.

Phase II. Identify the First Learning Episode

2. Simplest version. Help the SME to identify the simplest version of the task that is fairly representative of the task as a whole and to describe the conditions that distinguish that version from all other versions.

- It may be helpful to start by identifying some of the *major* versions of the task and the conditions that distinguish when one version is appropriate versus another.

* Try to distinguish elements of instructional theory from elements of the ISD process in the following.
** The idea of integration is a common feature in the new paradigm.
*** Did you recognize this as method and sub-methods?
**** What is the relationship between 1.1 and 1? Between 1.1 and 1.2?

- Thinking of different conditions helps to identify versions, and thinking of different versions helps to identify conditions. Therefore, it is wise to do both simultaneously (or alternately).
- Ask the SME to recall the simplest case she or he has ever seen. The simplest version will be a class of similar cases. Then check to see how representative it is of the task as a whole.
- There is no single right version to choose. It is usually a matter of trade-offs. The very simplest version of the task is usually not very representative of the task as a whole. The more representative the simple version can be, the better, because it provides a more useful schema to which learners can relate subsequent versions.
- You may want to use some other criteria in addition to simple and representative, such as common (how frequently performed the version of the task is) and safe (how much risk there is to the learner and/or the equipment).

3. Organizing content.[4] Analyze the organizing content for this version of the task. How you do this will vary depending on the nature of the task: procedural, heuristic, or a combination of the two. (This is done now rather than later because it is important for determining whether this version of the task will be too large or too small for a single episode.)

- If primarily *procedural*, perform a procedural task analysis to identify substeps at the entry level of description and draw a flowchart for this version of the task. (For more guidance, see Merrill, 1976; 1980; Reigeluth, in press.)
- If primarily *heuristic*, use the process described in the next section of this chapter to identify guidelines and decision rules in a performance model and to identify explanations in explanatory models.
- If *combination*, do both: identify substeps, guidelines, decision rules, and explanations and portray each graphically.

4. Supporting content. Analyze supporting content for this version of the task. (This is also important to do now so that you can determine whether this version of the task will be too large or too small for a single episode.)

4.1 Identify information, understandings, skills, metacognitive/higher order thinking skills, and affective qualities (e.g., attitudes) that are directly relevant to this version of the task and have not yet been acquired by the learners.

4.2 Analyze those understandings, skills, metacognitive/higher order thinking skills, and affective qualities down to entry level. The procedural and hierarchical task analysis approaches work well for skills and higher-order skills, and the hierarchical approach can be fairly easily extended to identifying prerequisite understandings. But I cannot offer much guidance for analyzing affective qualities.

[4]In the case of a procedural task, the organizing content is steps, whereas for a heuristic task, the organizing content is principles (heuristics).

At this point, you have identified all the content that needs to be taught in the episode for this version of the task. However, if you use an instructional approach that is highly constructivist and requires much self-directed and self-regulated learning, then you will not be explicitly teaching any supporting content. Nevertheless, it is helpful for the teacher (or guide) to be aware of all this supporting content, to provide appropriate scaffolding to the learner when needed, or to help the learner identify appropriate resources for learning important supporting content.

5. Size. Make sure the amount of learning required for this version of the task fits the size of the episodes for your course.

5.1. Decide how big your episodes should be.
- Analyze the delivery constraints of the specific instructional situation, if any (such as 45-minute time blocks for class sessions).
- Be sure to keep in mind both in-class and "homework" time.
- Too big is bad. In considering the optimal size of your groupings of content, consider how long your learners can be actively engaged without a break. This will depend to some extent on such factors as the age of the learners, the difficulty/abstractness of the content, the motivational value of the instruction, and additional factors.
- Too small is bad. Also consider how long the learners should be allowed to work in order to not interrupt their concentration and engagement.
- For less time-bound learning environments, size of episodes should be determined more by the considerations that Bruner (1960) talks about: ensuring that the "pay-off" for the learner is commensurate with the effort the learner invests. Also, there will be little need to make the episodes equal in size.

5.2. Adjust the size of the episode to the target size.
- If its length is greater than the target, reduce the size of this episode, preferably by adding another simplifying condition. It is possible to create simplifying conditions that don't exist in the real world to accomplish this if necessary, but there are obvious negatives in doing so. However, it is often possible to compensate for those negatives. Alternatively, some supporting content could be removed from this episode, but don't remove any prerequisites for the organizing content.
- If its length is much smaller than the target, increase the size of this episode, preferably by removing a simplifying condition (which requires adding skills).

6. Within-episode sequence. If you have decided to provide much guidance to the learner, you will want to sequence the content selected for this episode. But, if you intend to use a problem- or project-based learning approach with very little guidance, you may require the learner to figure out what learning resources he or she needs when. Either way, you may want to consider some of the following guidelines as you either make suggestions to the learner or decide on a within-episode sequence for the learner.*

- Teach prerequisites just prior to the content for which they are prerequisite.
- Teach understanding (principles, causal models, or process models) prior to a related procedure.
- Teach coordinate concepts together.
- Teach content in the order in which it is used (e.g., a procedural sequence).

At this point, if you are using a rapid-prototyping approach to ISD, you are ready to design and develop the instruction for this learning episode (the epitome). Otherwise, you can continue to Phase III to design the scope and sequence for each of your remaining episodes.

Phase III. Identify the Next Learning Episode

7. Next version. Help the SME to identify the next simplest version of the task that is fairly representative of the task as a whole.

7.1. Identify and rank-order all the simplifying conditions that distinguish the simplest version of the task from all the more complex versions.

- Each simplifying condition eliminates some skills and knowledge from what an expert needs, to be able to perform the task. Different conditions correspond to different sets of skills and knowledge that vary in complexity. This allows the simplifying conditions to be ranked according to how much additional complexity each requires for performance of the task.
- The rank-ordering of the simplifying conditions corresponds to an ordering of the versions of the task from simple to complex.
- The rank-ordering of the simplifying conditions should be done using the same criteria you used in step 2: how simple and representative the resulting version of the task is and any other criteria you choose, such as how common it is and how safe it is.
- Don't expect to be able to identify all of the simplifying conditions right away. As you proceed with the analysis, you will find additional conditions to add, no matter how thorough you try to be from the beginning.
- These simplifying conditions are referred to as the "primary simplifying conditions" (PSCs) because they are identified first. (Secondary simplifying conditions, or SSCs, are discussed next.)
- It is usually helpful to identify the full variety of versions of the task appropriate for this course.

* Hopefully, you have noticed many places where diversity of methods is either provided or accommodated by the elaboration theory.

7.2. Identify the next simplest and most representative version of the task (the next elaboration).

- This will typically be the next rank-ordered simplifying condition.
- If removing a PSC requires more new content than can be taught in one episode, then identify *SSCs* that can be included to reduce the complexity of the new version of the task that results when the PSC is removed.
- If SSCs are added, rank-order them.
- Note that episodes defined by removing a PSC (called "primary elaborations") must be learned after the simplest episode (the "epitome"), for they all elaborate on it. However, those episodes could be learned in any order in relation to each other, even though it is usually better to teach the simpler elaborations first. On the other hand, the episodes defined by removing SSCs (called "secondary elaborations") cannot be learned until after the related primary elaboration is learned, for they all elaborate on it.
- If you want to design a learner-controlled sequence, you can design the primary elaborations so that they can be selected in any order. However, sometimes this can result in a fair amount of redundancy, if skills learned in one elaboration are also required in another. Of course, computer-based instruction can be designed to eliminate any such redundancy, by keeping track of what has already been learned.

7.3. If SSCs are added, rank-order them (see step 7.1).

8. Organizing content, supporting content, size, and within-episode sequence. These steps are the same as steps 3–6 in Phase II.

9. Remaining versions. Repeat Phase III (except for step 7.1) for each remaining simplifying condition (primary, secondary, tertiary, etc.) until instructional time runs out or you have reached the level of expertise desired.

Again, I would like to emphasize that this characterization of the SCM analysis/design process is considerably abbreviated, especially with respect to the heuristic elements, but hopefully it gives some understanding, both by the guidance it offers and the illustration it provides.

Elaboration on Step 3: Organizing Content

Step 3 above called for analyzing the organizing content for the selected version of the task. For procedural content, there is an effective method already available: procedural analysis (see, e.g., Gagné, Briggs, & Wager, 1992, pp. 147–150; Merrill, 1976; 1980; Reigeluth, in press). But for heuristic tasks, I am not aware of much guidance for identifying the heuristics that an expert uses in performing any given version of a task. The major difference lies in the nature of the content that is analyzed, sequenced, and learned. Rather than a set of steps (with decisions and branches and paths), you must identify the underlying principles or causal models that experts use to perform the task. In work I have done, the following ideas have gradually evolved.

Experts use both descriptive and design (prescriptive) theories to guide their decisions. I refer to a design theory as a performance model (or set of performance models), each of which is a set of interrelated guidelines for attaining a given goal. And I refer to one kind of descriptive theory as an explanatory model (or set of explanatory models), each of which is an interrelated set of explanations as to why the guidelines work. This is usually related to another kind of descriptive model, which shows how a complex "object" works, for example, the human psyche in the task of psychotherapy, or a power plant in the task of power-plant maintenance and repair.

"Object" descriptive models are usually the easiest to analyze, because an expert tends to be fairly well aware of the way the "object" of interest works. Therefore, this is a good place to start. Explanatory descriptive models are easier to identify after you identify the performance models that they are to explain. Performance models are perhaps the most difficult to analyze, because experts are usually not overtly aware of many of the heuristics that guide their performances of the task, and it is easy to overlook whole sets of guidelines and explanations.

To address this problem, it is useful to use a top-down approach to analyzing a version of a heuristic task for an episode. The top, most general, level is the **goals** of the task (or subtask, if it is a combination task). For example, for the task "Determine the media for a course," the goals might include:

- the media will help the learner to master the objective;
- the media will be cost effective;
- the media fall within the constraints for the course development and implementation.

After identifying all the important goals, you can then think in terms of **considerations** for attaining each goal. Considerations are the major categories of causal factors that influence performance of the task. For example, for the third goal (within constraints), the considerations might include:

- budget,
- skills of the personnel available to teach the course, and
- availability of equipment for the course.

If there are lots of causal factors within a category (a consideration), then it is helpful to identify **subcategories** of causal factors. This helps to keep from overlooking some types of causal factors. Eventually, you are ready to identify specific **causal factors** for each category (or subcategory). For example, for the third consideration (equipment availability), the factors might include:

- amount of equipment,
- scheduling of equipment,
- alternative uses of equipment,
- features (capabilities) of equipment.

This is the lowest level of analysis you need to reach in the top-down process. Once you have identified causal factors, you need to analyze each causal factor to identify all **guidelines** an expert uses to perform this version of the task that involve the causal factor. For example, guidelines for the above factors might include (in respective order):

- If an insufficient amount of the equipment is available for the projected number of students, do not select that delivery system.
- If the equipment is not available at all the necessary times, do not select that delivery system.
- If the equipment is available and would otherwise go unutilized, there is a stronger need for you to select that delivery system.
- If the capabilities of the equipment do not meet the instructional needs, do not select that delivery system.

  (Note that these examples are intended to be illustrative, not exhaustive, and there may be more than one guideline for a given causal factor.)

You should also identify any **decision rules** an expert uses to combine the guidelines into a performance model. Finally, you are ready to identify specific **explanations** as to why each of the guidelines works and to combine the explanations into explanatory models.

In summary, these are some substeps for performing step 3 for heuristic or combination tasks:

1. Identify a *descriptive model* for any and all objects involved in performing the task.
2. Identify the *goals* for this version of the task under its conditions.
3. Identify all important *considerations* for attaining each goal. If there are a lot of causal factors for a consideration, identify *subconsiderations* for it.
4. Identify all important *causal factors* for each consideration (or subconsideration).
5. Analyze each causal factor to identify all *guidelines* (prescriptive principles) that an expert uses to perform this version of the task. Also identify any *decision rules* an expert uses to combine the guidelines into a performance model.
6. Identify *explanations* as to why each of the guidelines works and combine the explanations into explanatory models.

Space limitations prohibit listing the heuristics for performing each of these substeps. But please keep in mind that you should identify these components of task expertise even if you plan to take a constructivist approach to the instruction, for it will provide an understanding of the kinds of scaffolding that may be helpful to provide.

CONCLUSION

The purpose of the elaboration theory is to provide guidance for making scope and sequence decisions that support much more holistic approaches to learning, which is especially important for the new paradigm of instructional theories. It recognizes that different guidelines are needed for different instructional situations. At this point, the differences are based on different kinds of expertise to be developed, but the elaboration theory is definitely a work in progress, and much remains to be learned about sound guidance for making scope and sequence decisions. I hope that this progress report will stimulate others to help contribute to this growing knowledge base.

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