Chapter 7

Conceptual Elaboration Sequencing: How to Do It

This chapter provides guidance on how to design, and conduct analyses for, conceptual elaboration sequences. Chapters 4-6 provided similar guidance for hierarchical, procedural, and simplifying conditions sequences, and Chapter 8 does so for the theoretical elaboration sequence. I strongly recommend you have a firm understanding of the theory of conceptual elaboration sequencing from Chapter 3 before you begin this chapter.

As discussed in Chapter 3, to design a conceptual elaboration sequence, you need to identify concepts that are parts and/or kinds of each other. Then you design a sequence that teaches the broadest concepts first and gradually works down to progressively more narrow parts or kinds, one level of detail at a time, in either a topical or spiral fashion. So, again, the most difficult part of the design process is analyzing concepts for their parts or kinds. The conceptual analysis process is therefore described first, followed by the sequence design process.

Conceptual Analysis Process

How to Do It

You conduct a conceptual analysis by identifying several important concepts in the domain of interest and asking the question, "What concepts are kinds or parts of these concepts?" or "What concepts are these concepts parts or kinds of?" In addition to that rule of thumb, you may find the following guidance helpful. In the next section, an example of this guidance process is provided, followed by an example of the resulting analysis. You may want to refer to those examples as you read through this guidance.

1. Prepare. Prepare for analysis. [No change from previous ones.]

- Establish rapport with a SME. Again, try to have a SME who also has experience teaching the content domain of interest to the target student population, so you can easily identify the concepts that the learners should already know.
- Identify the nature of the content domain in general.
- Identify the characteristics of the learners in general.
- Identify the delivery constraints of the instruction in general.

2. Analyze and select concepts. Identify all the concepts that the learner needs or wants to learn. This can be done by using the following substeps.

2.1 Make sure the SME understands the definition of a concept as a class of objects, events, or ideas that have either characteristics or functions in common. Also, make sure the SME understands the notions of superordinate, coordinate, and subordinate relationships among concepts, and the notion of parts-ordinate and kinds-ordinate varieties of those relationships (see Figures 7.1 and 7.2 for examples of those varieties of relationships.

2.2 Help the SME identify some of the more general and inclusive concepts in the content domain to be taught.

2.3 For each of the concepts identified in Step 2.2, help the SME to derive both a parts-conceptual structure (see Figure 7.1) and at least one kinds-conceptual structure (see Figure 7.2).

Parts. This can be done by dividing each concept into its most general parts, and then each of those parts into its parts, and so on until you reach the level of detail and complexity that the learner needs or wants to learn.

- The traditional tree diagram is difficult to draw and revise, so I recommend representing the conceptual structure in outline form, as is shown in Figures 7.1 and 7.2.
- Of course, it is possible that the learner does not need or want the concept broken down at all into parts.

You should also consider what concept your initial concept is a part of, and decide whether or not it should be included. In this way, you analyze down from the concept and possibly up from the concept, depending on whether or not you started with a broad enough concept.

- Please note that unlike a learning hierarchy (see Chapter 4), going further down in a parts-conceptual structure does not increase the likelihood of the concept being entry knowledge for the learners.

Kinds. The same process should be used for one or more kinds-conceptual structures: dividing each concept into its most general kinds, and then each of those kinds into its kinds, and so on to the desired level of detail.

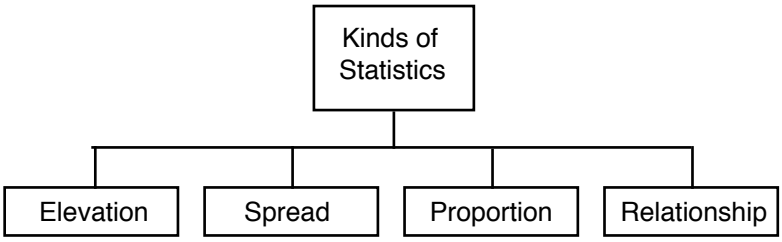
- There is usually more than one dimension, or way, in which a concept can be divided into kinds. For example, trees can be divided according to their genus (oaks, maples, etc.) or their size (seedlings, saplings, etc.), or their climate (tropical, subtropical, etc.).
- It could be that no kinds of a given concept are of relevance to the learner, or it could be that five dimensions of kinds are all relevant.
- Each conceptual structure should generally be outlined on a different piece of paper, to avoid confusion and to make it easier to add concepts to it.

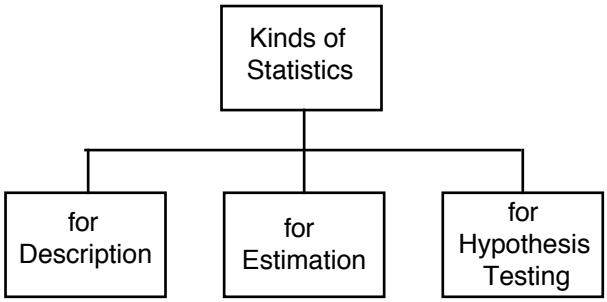
2.4 Help the SME check to make sure that all concepts identified are appropriate to include in this course and that no important concepts have been left out.

3. Select the organizing structure. Select one of the conceptual structures to provide the sequencing "skeleton" for the course or curriculum. It is called the "organizing structure." (Other conceptual structures or individual concepts will later be "fleshed" onto relevant parts of that skeleton.) This can be done by using the following substeps.

3.1 Help the SME to decide which conceptual structure contains the most inclusive and important of all the concepts that were selected in Step 2 (i.e., which conceptual structure has the concepts that subsume the greatest number of all the concepts for the course, and includes the most important concepts in relation to the goals of the course). Also, help the SME to decide if a table could be created that would serve as a good skeleton for the sequence of the course or curriculum.

- Sometimes, the most important concepts are identified by a table (or matrix), where each dimension of the table is taken from a single row of a different conceptual structure. The intersection of the two dimensions identifies a third set of concepts that are subordinate to each of the two dimensions. For example, Darlington (1975) identified two different kinds-conceptual structures for statistics:





And for hypothesis testing, he identified statistics for one unknown value, two unknown values, and three or more unknown values of a parameter. He then sequenced a statistics textbook around the table formed by crossing the two conceptual structures:

	Elevation	Spread	Proportion	Relationship
Description				
Estimation				
Hypothesis Testing 1				
Hypothesis Testing 2				
Hypothesis Testing 3+				— —

Each of the cells in this table represents a different kind of statistical methods, except for the one in the lowest right corner, according to Darlington. As you will see later, there will not necessarily be exactly one chapter per cell of the table, because some cells have a lot more supporting content to be learned than do others (see Step 4).

3.2 Number the levels of elaboration in the organizing structure.

- The top box in the organizing structure is usually entering knowledge for the learners, so we generally number it "0." The first row of boxes under it is then numbered "1," the next row "2," and so forth.
- This is important, because no concept should be taught until the concept directly above it has been taught. This is what determines a conceptual elaboration sequence.

4. Identify supporting content. Help the SME to identify all the remaining content that the learner needs or wants to learn, and identify the concept (or row of concepts) to which it is most closely related and with which it should therefore be taught. This decision needs to be made before the sequencing can be done, because sequencing and grouping decisions must be done together (see Chapter 3), and you don't know how big a group (how much learning time) a given organizing concept will take until you know how much supporting content should be learned in the same learning episode. This can be done by using the following substeps.

4.1 For each of the other **conceptual structures** you identified in Step 2, help the SME to identify the concept (or row of concepts) to which it is most closely related and with which it should therefore be taught.

- Sometimes different concepts in a supporting conceptual structure will best be allocated to different concepts in the organizing structure.
- You can use a letter or number scheme to indicate which supporting structures (or individual concepts) will go with which concepts in the organizing structure.

4.2 Help the SME to identify all **procedures** (sets of steps) that are important for the learner, and identify the concept (or row of concepts) to which each is most closely related and with which it should therefore be taught.

- Again, you can use a letter or number scheme to indicate which procedures will go with which concepts in the organizing structure.

4.3 Help the SME to identify all **principles** (natural processes, cause-effect relationships, or guidelines for attaining a goal) that are important for the learner, and identify the concept (or row of concepts) to which each is most closely related and with which it should therefore be taught.

- Again, you can use a letter or number scheme to indicate which principles will go with which concepts in the organizing structure.

4.4 Help the SME to identify all other important kinds of content, such as **information, understandings, thinking skills** (including learning strategies and metacognitive skills), **attitudes and values, and even dimensions of emotional, social, and spiritual development,** and identify the concept (or row of concepts) to which each is most closely related and with which it should therefore be taught.

- Again, you can use a letter or number scheme to indicate which content will go with which concepts in the organizing structure.

5. Group the content into learning episodes and sequence them. Help the SME to allocate all content within each level of elaboration to episodes, and sequence the episodes. This can be done by using the following substeps.

5.1 Decide whether or not the learners will be allowed to make sequencing decisions, and if so, which decisions.

- Some sequencing decisions may be unwise to give to the learners, whereas others could beneficially be made by them.

  For example, if a learner has just completed the episode related to a given box in Figure 7.**, it is usually unwise for the learner to proceed directly to a box two levels lower. The learner should generally only go down one level at a time.

  On the other hand, when a learner has completed an episode related to a given box in Figure 7.**, it would be fine to proceed to the episode for *any* one of the boxes directly below it, or to the episode for *any* one of the boxes coordinate to it, or even to the episode for *any* one of the boxes directly below any other box that the learner has already mastered. Affording the learner such freedom and initiative is generally good for the learner's motivation and metacognitive skill development.

- It is important to know if learners will be allowed to make sequencing decisions, because some redundancy across learning episodes is often needed when they are given that freedom. For example, two episodes that are on the same level of elaboration may have some common skills or understandings, in which case those common content elements would need to be included in both

episodes for a learner-determined sequence, but only in one episode for a designer-determined sequence.

- The issue of "which decisions" in 5.1 above is basically deciding what options the learner will have after completing each episode. The options are the episodes that the learner will be allowed to choose next.

5.2 Decide how big the learning episodes should be for your course (see p. 4.5 for guidance).

- In many contexts time is rigidly controlled, and you cannot change that constraint. In that case, you may be forced to go with anything ranging from 45-minute periods plus homework time, to full-time study for a two-week workshop. At most, you will be able to choose between, say, one 3-hour class or three 50-minute classes per week.
- In other contexts, you may be free from the shackles of time to personalize the instruction for each learner and to allow each learner to take whatever amount of time she or he needs to master the content. In that case, your episodes don't have to all be the same size. You can put greater emphasis on whatever groupings are logical, cohesive, and effective.
- Keep in mind that the end of each episode is a natural time for review and synthesis. Hence, if the episodes are too long, there will be too much new material before the review and synthesis arrives. On the other hand, if the episodes are too short, too much time will be spent on review and synthesis. Also, keep in mind Bruner's caution that the longer a learning episode is, the larger must be the learner's satisfaction upon completion of the episode, in order to sustain motivation. You should adjust the size of your episodes accordingly.

5.3 Pick a box, including the organizing concept and all the supporting content that was allocated to it, and adjust its size to the size of your episodes, if necessary.

- Start at the top of the organizing structure and work your way down, because that is the general order in which the episodes will be sequenced. It will give you a better feel for what the student will be experiencing.

If the content is too small, you may need to figure out what other box to combine it with, or just plan to teach it and another episode in the single time period.

- Whether you decide to combine two boxes into a single episode or you decide to teach two episodes in a single time period, it is usually wise to make sure the two boxes are coordinate concepts (on the same level of the conceptual structure), to maximize their relatedness.

If the content is too big, you'll need to figure out how to divide it into two or more episodes, or just plan to take more than one time period for learning the content.

- If you combine content from two different boxes, try to pick content that is most closely related in the two boxes, so that the combination episode will have some coherence.

5.4 Make any episode sequencing decisions that should not be left up to the learners, as determined in Step 5.1.

- The primary criterion for episode sequencing decisions should be the principle of conceptual elaboration, which states that a broader, more general organizing concept should be learned before a narrower, more specific organizing concept that elaborates on it.
- Aside from the constraint of that primary criterion, I recommend you usually provide as much learner control over sequencing as you can within your cost-effectiveness constraints.
- If cost-effectiveness constraints prohibit you from providing that much learner control, a secondary criterion for episode sequencing decisions is learning load. *Learning load* is defined as the amount of difficulty and time it takes a learner to learn the content to the extent desired. The learning-load criterion entails making the learning load as even as possible across the episodes. Learning load is influenced by the amount of content to be learned, the familiarity of the content to the learner, and undoubtedly other factors. If there is much overlap between two coordinate episodes (e.g., some of the same prerequisite skills or understandings are required in both), then the episode that is learned later will be easier to learn. These factors should all be balanced against each other in making additional sequencing decisions.

  The following is the sequence Darlington (1975) used in his statistics textbook:

	Elevation	Spread	Proportion	Relationship
Description		Ch. 3		Ch. 6
Estimation		Ch. 4		
Hypothesis Testing 1	Ch. 9		Ch.14	Ch.16
Hypothesis Testing 2	Ch.10	Ch.13	Ch.15	Ch.17
Hypothesis Testing 3+	Chs. 11-12		Ch.16	——

6. Sequence the content within each episode. Help the SME to sequence all content within each learning episode. This can be done by using the following substeps.

6.1 Identify any unmastered learning prerequisites for any of the content in the episode. (See Chapter 4.)

6.2 Decide whether or not the learners will be allowed to make any sequencing decisions within each episode, and if so, which decisions. Doing Step 6.3 simultaneously will help you decide.

- There will almost always be trade-offs. Allowing learners to make decisions will increase motivation and metacognitive skill development, but will take more time and effort. The value placed on each of those costs and benefits will tend to vary from one situation to another.

6.3 Use the following principles to identify any within-episode sequencing decisions that might be beneficial to make for the learners, and design the corresponding sequences.

- Teach a prerequisite just before it will be needed, preferably right after the learner realizes it is needed.
- Teach coordinate concepts together, comparing and contrasting them with each other.
- Teach understanding before related performance skill.
- Teach simpler and more familiar content before more complex and less familiar content.
- Teach broader, more inclusive, less detailed ideas before narrower, less inclusive, more detailed ideas.
- Allow the learner to make as many selection and sequencing decisions as you can, within your cost-effectiveness constraints, but be sure to provide

opportunity for reflection or feedback on the soundness of the learner's decisions.

Job Aid for the Conceptual Elaboration Sequence

1. Prepare
   Establish rapport with the SME.
   Identify characteristics of the content domain in general.
   Identify characteristics of the learners in general.
   Identify delivery constraints of the instruction in general.

2. Analyze and select concepts
   2.1 Make sure SME understands concept, super/co/subordinate, parts/kinds-ordinate.
   2.2 Identify the more general, inclusive concepts.
   2.3 Derive parts- and kinds-conceptual structures.
   2.4 Check concepts for appropriateness and check for missing concepts.

3. Select the organizing structure
   3.1 Decide which structure is the most inclusive and consider a matrix (or table).
   3.2 Number the levels of elaboration.

4. Identify the supporting content
   4.1 Allocate other conceptual structures to concepts or rows in organizing structure.
   4.2 Identify and allocate procedures to concepts or rows in the organizing structure.
   4.3 Identify and allocate principles to concepts or rows in the organizing structure.
   4.4 Identify and allocate other content to concepts or rows in the organizing structure.

5. Group the content into learning episodes and sequence them.
   5.1 Decide which sequencing decisions learners should make.
   5.2 Decide how big the learning episodes should be.
   5.3 Pick a box (including its supporting content) and adjust its size.
   5.4 Make any episode sequencing decisions not left up to the learners.

6. Sequence the content within each episode.
   6.1 Identify any unmastered learning prerequisites for all content.
   6.2 Decide which sequencing decisions learners should make.
   6.3 Identify any sequencing decisions to make for the learners and design them.

Process Example: Life Science

By Amy Werner

Here is an example of the process for conducting a conceptual analysis and designing a conceptual elaboration sequence, using the guidance provided in the previous section. The sequence is for the life science portion of a seventh grade integrated science class. An integrated science class is one that includes life, earth and physical sciences. Specifically, we wanted to design instruction on the systems of the body. This content is largely a series of related concepts. It includes a few principles and fewer procedures.

1. Prepare

I served as my own subject-matter expert (SME) for this project. The target learners were seventh grade science students. These students could vary greatly in their backgrounds and abilities. This segment of the class would be several weeks in duration. The instruction was designed on the assumption that teachers would be restricted to 45 or 50 minute class periods. Constraints on media and materials would vary from school to school; however, the instruction could be structured around available materials.

2. Analyze and select concepts

2.1 Make sure the SME understands the definition of a concept.

I reviewed literature to be sure I had an understanding of the definition of a concept as well as superordinate, coordinate and subordinate concepts.

2.2 Help the SME identify some of the more general and inclusive concepts.

Identifying the most inclusive concepts for the systems of the body was easy, as the most inclusive concepts are the systems themselves. All other concepts I wanted students to learn are parts or kinds of the systems. The following are some of the major concepts:

- Digestive system
- Resperatory system
- Muscular system
- Nervous system
- Circulatory system
- Excretory system
- Skeletal system
- Reproductive system

2.3 Help the SME to derive several highly inclusive conceptual structures.

Deriving the kinds structures proved to be more difficult than the parts. In fact, for some concepts (or systems) I was not able to define a kinds structure at all. I relied on my experience teaching seventh-grade science to determine when I had reached the appropriate level of complexity. Figure 7.1 shows a parts-conceptual structure, and Figure 7.2 shows a kinds-conceptual structure.

- Human Body
  - Digestive system
    - Mouth
      - Teeth
        - Crown
        - Root
        - Enamel
      - Tongue
        - Taste buds
      - Saliva
        - Digestive enzymes
        - Mucous
    - Throat
      - Epiglottis
      - Esophagus
      - Pharynx
      - Peristalsis
    - Stomach
      - Chyme
        - Gastric juices
      - Pyloric spincter
    - Small intestine
      - Duodenum
      - Villi
    - Large intestine
      - Rectum
      - Reabsorption
  - Circulatory system
    - Heart
      - Atria
      - Ventricles
      - Vena cava
      - Valves
      - Aorta
    - Blood vessels
      - Arteries
      - Veins
    - Blood
      - Plasma
      - Platelet
      - Red blood cells
      - White blood cells

Figure 7.1 A parts-conceptual structure (Continued)

- Respiratory system
  - Larynx
    - Vocal cords
  - Trachea
    - Cilia
    - Mucus
  - Lungs
    - Bronchial tubes
    - Alveoli
    - Pulmonary arteries
    - Pulmonary veins
  - Diaphragm
- Excretory system
  - Kidneys
    - Renal medulla
    - Renal cortex
    - Nephron
    - Capillaries
    - Collecting duct
  - Urinary bladder
  - Ureters
  - Renal artery
  - Renal vein
- Muscular system
  - Contractile cells
    - Actin
    - Myosin
    - Sarcolemma
    - Motor axon
    - Neuromuscular junction
  - Insertion
  - Origin
  - Tendon
- Skeletal system
  - Bone
    - Spongy bone
    - Bone marrow
    - Compact bone
  - Joint
  - Ligament
  - Cartilage
  - (Tendon)
- Nervous system
  - Brain
    - Medulla
    - Pons
    - Cerebellum
    - Hypothalamus
    - Thalamus
    - Cerebrum
  - Spinal cord
    - Gray matter
    - White matter

Figure 7.1 A parts-conceptual structure (Continued)

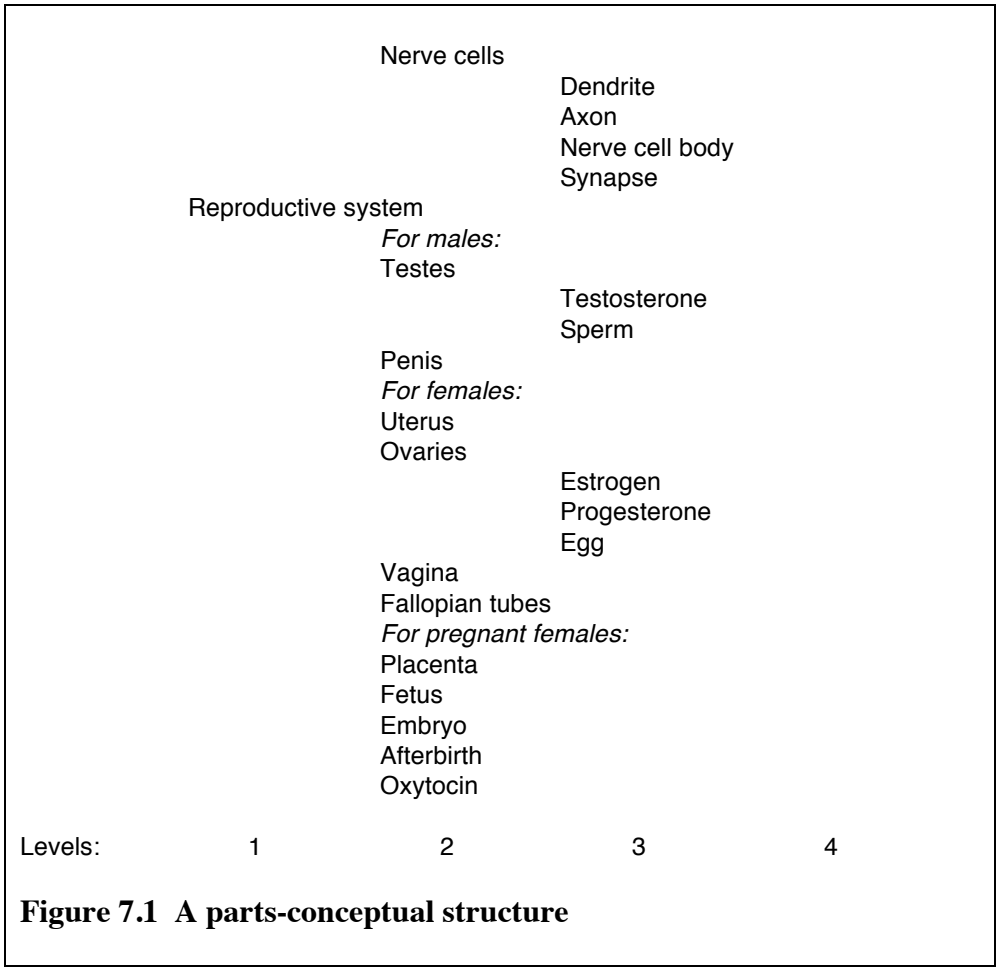


Figure 7.1 A parts-conceptual structure

(To be developed)

Figure 7.2 A kinds-conceptual structure

2.4 Check to make sure you have the right concepts.

I went back over the structures several times to be sure I had included all of the concepts that I wanted the students to learn but had not included any that were inappropriate or unnecessary. I ended up making additions to the parts structure at several points during the remainder of the process.

3. Select the organizing structure

3.1 Decide which conceptual structure will be the organizing structure.

The parts-conceptual structure (Figure 7.1) was the obvious choice as an organizing structure for the course. It included many more concepts than any of the kinds structures, which, in some cases, I was not able to define at all.

3.2 Number the levels of elaboration in the organizing structure.

I labeled the human body as 0 because seventh-grade students have an understanding of that concept. On the other hand, I felt that some instruction was needed on the systems themselves because some seventh-grade students may lack an understanding of some of the purposes or functions of some systems in the body. Therefore, the second column from the left was labeled 1 and the remaining columns were labeled 2, 3 and 4 in order (see Figure 7.1).

4. Identify supporting content

4.1 Allocate the other conceptual structures.

I went through the kinds structures that I was able to derive, determined which were appropriate to teach (cardiac, smooth, and skeletal muscle, for example) and decided which concepts in the organizing structure to which they were most closely related. For example, the structure shown in Figure 7.2 was allocated to ***.

4.2 Identify and allocate procedures.

I went through each concept in the organizing structure and thought about what procedures I would want the students to learn while studying that system or part. Most of the procedures I identified were those related to experiments or investigations I would want to carry out. For example, the following were identified:

- Drawing a line graph
- Taking a pulse
- Heimlich maneuver
- Using a light microscope.

4.3 Identify and allocate principles.

I began by reviewing the definition of a principle. Then I again went through each concept in the organizing structure and thought about what principles I would want the students to learn while studying that concept. I found only one or two which were appropriate:

- Interrelationships and interdependencies among the systems
- Interactions of the systems with the environment
- The process of digestion
- Process of inhaling and exhaling
- The harder our muscles work, the more oxygen they need, so we breathe faster
- Chewing more creates more surface area for the food, which causes faster digestion
- Effects of smoking
- Gas exchange: more surface area allows more oxygen absorption
- Sliding Filament Theory
- The process of muscle contraction
- The process of conception
- Principles of proper dental care
- The cause of heartburn.

4.4 Identify and allocate all other important kinds of content.

Other content that I would want the students to learn focused mainly on two areas. First, I feel strongly about students learning the scientific method. Second, I feel it is important for students to learn about some of the diseases that can affect the different systems of the body. So, for each organizing concept, I identified any such content that seemed relevant. Here is a sample:

Information

- What blood carries: oxygen, carbon dioxide, nutrients
- The typical length of a menstrual period
- Normal range for blood pressure

Attitudes

- Desire to take good care of your body
- Appreciate the importance of prenatal care
- Appreciate the importance of proper dental care

Thinking skills

- Hypothesizing
- Analyzing data
- Drawing conclusions.

5. Group the content into learning episodes and sequence them

5.1 Decide what sequencing decisions students should make, if any.

I think it would be beneficial in this case to allow students to make some of their own sequencing decisions. Although the systems of the body are closely related to one another, it should not matter which one is taught first. At this level, knowledge of one system is not necessary to understand another. If time constraints allow for students to work independently at their own pace, I would suggest having them select the order in which they would like to learn the systems. Within each system, however, the students should follow the top-down sequencing, as the concepts get more difficult and specific and depend on the concepts directly above them.

5.2 Decide how big your learning episodes should be for your course.

Ideally each episode would take 45 to 50 minutes as this is the normal length of a class period in the public schools.

5.3 Adjust the size of this learning episode, if necessary.

For the most part, each elaboration for each system supplied just about enough content for a 45- to 50-minute episode. In a few cases some were broken into two episodes.

5.4 Make episode sequencing decisions.

The sequencing decisions that will not be left up to the students are following the top-down sequence within the organizing structure, as one episode provides a basis for understanding the ones that elaborate on it. Students may, however, choose the order in which they want to learn the episodes that elaborate on any given episode. For example, the body systems can be learned in any order. Although the systems are related to and dependent on one another, knowledge of one is not essential for understanding another.

6. Sequence the content within each learning episode.

6.1 Identify any unmastered learning prerequisites

I reviewed every concept, principle, and procedure for learning prerequisites and found a number of them. For example, a prerequisite for digestive system is digestion; a prerequisite for urinary bladder is bladder; and a prerequisite for understanding systolic and diastolic pressure is the concept of a two-chamber heart.

6.2 & 6.3 Make any within-episode sequencing decisions.

Within each learning episode, sequencing was often determined by the order of the process the system carries out. For example, when learning the parts of the heart, it is helpful to learn them in the order they occur in the process of a heartbeat or blood flow. In other cases, such as within the skeletal system, there is no process involved, and one concept is not a prerequisite for another. Therefore, the order in which the part-concepts are learned is immaterial, and it is beneficial to allow the learners to decide the order of the content within this type of episode.

Product Example

Here is the final result of the above process for analyzing and designing a conceptual elaboration sequence for systems of the body.

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Epitome Level

Episode 1 Systems of the Human Body	**Time: 1 hour**
Organizing Content	**Supporting Content**
1. Digestive system 2. Circulatory system 3. Respiratory system 4. Excretory system 5. Muscular system 6. Skeletal system 7. Nervous system 8. Reproductive system (Numbers correspond to episode numbers in the next level.	Digestion Transportation Gas exchange Waste products Movement Support Information Offspring Interrelationships and interdependencies among the systems The body as an engine Interactions of the systems with the environment

Second Level

Episode 2.1 The Digestive System	**Time: 1 hour**
Organizing Content	**Supporting Content**
Mouth Throat Stomach Small intestine Large intestine	The digestive process Mechanical breakdown Chemical breakdown Ulcer

Episode 2.2 The Circulatory System	**Time: 1 hour**
Organizing Content	**Supporting Content**
Heart Blood vessels Blood	Drawing a line graph Pulse (healthy heart rate) Taking a pulse What blood carries: oxygen, carbon dioxide, nutrients

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Episode 2.3 The Respiratory System	Time: 1 hour
Organizing Content	**Supporting Content**
Larynx Trachea Lungs Diaphragm	Lung capacity Process of inhaling and exhaling

Episode 2.4 The Excretory System	Time: 1 hour
Organizing Content	**Supporting Content**
Kidneys Urinary bladder Ureters Renal artery Renal vein	Kidney transplant Homeostasis Bladder

Episode 2.5 The Muscular System	Time: 1 hour
Organizing Content	**Supporting Content**
Contractile cells Insertion Origin Tendon	Cardiac, smooth, and skeletal muscles 10 muscles: bicep, tricep, gastrocnemius, quadricep, trapezius, deltoid, gluteus maximus, gluteus minimus, latissimus dorsi, rectus abdominus The harder muscles work, the more oxygen they need, so we breathe faster

Episode 2.6 The Skeletal System	Time: 1 hour
Organizing Content	**Supporting Content**
Bone Joint Ligament (Tendon) Cartilage	Bone growth Fracture (simple, compound) Scoliosis 10 bones: phalanges, clavicle, humerous, radius, ulna, femur, fibula, tibia, scapula, sternum

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Episode 2.7 The Nervous System	Time: 1 hour
Organizing Content	**Supporting Content**
Central nervous system: brain, spinal cord Peripheral nervous system: nerve cells	Reflexes Input/output process Paralysis Types of nerves sensory, motor Backbone/ vertebrae

Episode 2.8 The Reproductive System	Time: 1 hour
Organizing Content	**Supporting Content**
Female: uterus ovaries vagina fallopian tubes Male: testes penis Pregnant female: placenta fetus embryo afterbirth oxytocin	Puberty Pregnancy Menstrual period Ejaculation Labor

Third Level

Episode 3.1 The Digestive System	Time: 1 hour
Organizing Content	**Supporting Content**
Mouth: Teeth Tongue Saliva Throat: Epiglottis Esophagus Pharynx Peristalsis Stomach: Chyme Pyloric sphincter Small intestine: Duodenum Villi Large intestine: Rectum Reabsorption	Choking Heimlich maneuver Surface area Chewing more ---> more surface area ---> faster digestion

Contiinued

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Episode 3.2 The Circulatory System	Time: 2 hours
Organizing Content	**Supporting Content**
Heart: Atria Ventricles Vena cava Valves Aorta Blood vessels: Arteries Veins Blood: Plasma Platelet Red blood cells While blood cells	Systolic pressure Diastolic pressure High blood pressure Heart attack Pulmonary circulation Systemic circulation Using a light microscope Hemaphilia Transfusion Phagocytosis

Episode 3.3 The Respiratory System	Time: 1 hour
Organizing Content	**Supporting Content**
Larynx: Vocal cords Trachea: Cilia Mucus Lungs: Bronchial tubes Alveoli Pulmonary arteries Pulmonary veins	Effects of smoking Emphysema Gas exchange: more surface area → more oxygen

Episode 3.4 The Excretory System	Time: 1 hour
Organizing Content	**Supporting Content**
Kidneys: Renal medulla Renal cortex Nephron Capillaries Collecting duct	Dialysis Filtration Antidiuretic hormone

Episode 3.5 The Muscular System	Time: 1 hour
Organizing Content	**Supporting Content**
Contractile cells: Actin Myosin Sarcolemma Motor axon Neuromuscular junction	Muscular dystrophy Sliding Filament Theory Muscle contraction

Contiinued

[This page should point out important aspects of the blueprints on the right.]

Episode 3.6 The Skeletal System		Time: 1 hour
Organizing Content		**Supporting Content**
Bone:	Spongy bone Bone marrow Compact bone	Appendicular skeleton Axial skeleton Osteoporosis
Joint:		Pivotal joint Ball-in-socket joint Hinge joint Gliding joint
Cartilage:	Matrix	

Episode 3.7 The Nervous System		Time: 1 hour
Organizing Content		**Supporting Content**
Brain:	Medulla Pons Cerebellum Hypothalamus Thalamus Cerebrum	Brain damage Function of each part of the brain Nerve impulse
Spinal cord:	Gray matter White matter	
Nerve cell:	Dendrite Axon Nerve cell body Synapse	

Episode 3.8 The Reproductive System		Time: 1 hour
Organizing Content		**Supporting Content**
Ovaries:	Estrogen Progesterone Egg	Prenatal care Infertility Conception
Testes:	Testosterone Sperm	

Contiinued

[This page should point out important aspects of the blueprints on the right.]

Fourth Level

Episode 4.1 The Digestive System		**Time: 1 hour**
Organizing Content		**Supporting Content**
Teeth:	Crown Root Enamel	Cavity Proper dental care Heartburn
Tongue:	Taste buds	
Saliva:	Digestive enzymes Mucous	
Chyme:	Gastric juices	

The following critical thinking skills should be emphasized throughout the elaboration sequence as part of the scientific method:

- hypothesizing
- analyzing data
- drawing conclusions

Practice Exercises

If you are using this book in a course and you want to use a problem-based learning approach to learning these skills and understandings, you should begin by selecting a problem and scenario that fit the criteria outlined below, and use the relevant prior material in this book on an as-needed basis.

I recommend you choose your own scenario and problem for this exercise, for then it will be more personally relevant and authentic. But if you do so, it is important that the scenario and problem meet certain criteria, or they will not afford you the opportunity to learn to do a conceptual analysis and sequence design. Here are the criteria.

The Problem

- The content domain should be relatively simple. Picking a more complex one will just make your project take longer, without enhancing your learning much. It may be based on a kinds-conceptual structure, a parts-conceptual structure, or a matrix structure. In fact, it would be more useful to do two projects with different kinds of structures than to do a project with one complex structure of just one kind.
- The problem should only entail designing the sequence at this point, unless you are using this book in conjunction with other resources that can help you to design additional aspects of the instruction.

The Scenario

- Work on a team of 2 (or at the most 3) people to perform this project. You will learn more by sharing ideas and perspectives with each other. You will also further build your teaming skills, which are extremely important for instructional designers. I have found that the more people beyond two on a team, the less active involvement and learning will take place for at least one of the teammates.
- Try to find a real client for whom to do the project, in a school (k-12 or higher education), corporate (profit or nonprofit), or informal setting. If you can't find a real client, then arrange for a classmate or friend to be your client in a role-play type situation. Your client should serve as your subject-matter expert.

A Sample Problem and Scenario

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What's Next?

If you are studying these chapters in order, Chapter 8 provides a similar skill-building focus on how to design, and conduct analyses for, theoretical elaboration sequences. Whether you proceed to Chapter 8 or to a different chapter, be sure you have a good understanding of a sequence from Chapter 3 before you go to its corresponding skill-focused chapter.

References

Darlington, R.B. (1975). *Radicals and Squares*. Ithaca, NY: Logan Hill Press.