Chapter 5

Procedural Sequencing: How to Do It

This chapter provides guidance on how to design, and conduct analyses for, procedural sequences (sometimes called "information-processing" sequences). Chapter 4 provided similar guidance for hierarchical sequencing, and Chapters 6-8 do so for the other three major sequencing strategies: simplifying conditions, conceptual elaboration, and theoretical elaboration. I strongly recommend that you have a firm understanding of the theory of procedural sequencing from Chapter 3 before you begin this chapter.

As discussed in Chapter 3, to design a procedural sequence, you need to identify steps that are procedural prerequisites for other steps (i.e., they must be performed before the other steps can be performed). Then you design a sequence that teaches the prerequisite steps first. So the most difficult part of the design process is analyzing steps for their procedural prerequisites. The procedural task analysis process is therefore described first, followed by the procedural sequence design process.

Procedural Task Analysis Process

How to Do It

According to Paul Merrill (1976), you conduct a procedural task analysis by asking the question, "What does an expert do first?" and "What does an expert do next?" until the entire task is described.

But there are two major ways this can be done. One is to conduct a **pure** procedural analysis by identifying all the steps of the procedure in a "first-to-last" order, starting with the first step, and describing each step at a level that the target population of learners can understand (entry level). When decision steps are encountered, you follow one branch to completion, then return to follow another branch to completion, until all branches have been described. The second approach is to conduct a

combination procedural and hierarchical analysis by identifying the steps in a "top-down" manner— identifying the major steps first, then breaking each step into substeps, each substep into sub-substeps, and so forth until you reach entry level. This approach is based largely on the Extended Task Analysis Procedure (Reigeluth & Merrill, 1984).

The top-down approach is generally preferred for large tasks because it offers a more holistic view of the task and thereby reduces the chances of leaving out any important parts (branches) of the procedure. For small procedures, the first-to-last approach is generally preferred because it is quicker.

The following guidance uses the combination (top-down) approach. In the next section, two examples of this guidance process are provided, followed by examples of the resulting task descriptions. You may want to refer to these as you read through this guidance.

1. Prepare. Prepare for analysis. (This is the same as for hierarchical analysis.)

1.1 Establish rapport with a SME.

1.2 Identify the characteristics of the task in general, so you will gain a general understanding of the task.

1.3 Identify the characteristics of the learners in general.

1.4 Identify the delivery constraints of the task in general.

2. Identify steps. Select a procedural task that the learner needs or wants to learn, and help the SME describe a small number of steps for doing a complete performance of the task.

2.1 List and order the steps. Help the SME to break down the task into steps (or the step into substeps). This entails thinking of and listing the major steps for performing the task (or substeps for performing the step), and arranging them in the optimal order of performance.

- This primarily entails breaking the *action* involved in the step down into more precise, detailed, and/or specific actions and/or decision criteria. State each action or decision in the form of a step, using an active verb. This is basically the rule-analysis portion of a hierarchical task analysis (see pp. 4.2 - 4.3).
- Usually, about 3-9 steps are good. If you have more than about nine steps, then try collapsing some of

them into a more general step. If you have less than about 3, try expanding at least one into several more detailed steps.

- As you get to more detailed levels in your breakdown of steps, it is often helpful to have the SME actually perform the task (or a part of the task) and "think aloud" during the process so you can "see" the unobservable, mental steps. Such observation is even more useful in the pure (first-to-last) approach to procedural task analysis.
- In many cases, the order of performance of some steps does not matter at all, while in other cases it matters a lot. In cases where it doesn't matter at all, it is usually still helpful to pick a typical order that an expert uses, and use that order in your sequence. (But it is also helpful at some point in the instruction to let the learners know when the order is arbitrary.)
- If the task can be done in quite different ways (each of which represents a different branch of the procedure), ask the SME to have a "typical" way in mind when describing the steps for you.

2.2 Identify any other ways. Ask the SME to review the steps to determine whether there are other ways the task should be done, depending on conditions. If there are, then identify branches based on the alternate steps, and identify decision steps based on the conditions.

- Be careful not to describe performances that represent personal preferences or ideosyncracies of the SME. Identify only generally accepted ways.
- When there is more than one way to do the step, for a single situation, it is usually best to describe only the one best way of doing it, because teaching several ways often results in none of them being learned well, and it is more time-consuming. If the best way varies from situation to situation, then you need a decision step and a branch for each best way (see step 2.3 below).
- Make sure that at least two branches result from each decision step.

2.3 Check the steps. Ask the SME to review the steps to ensure the presence of all steps, including decision steps and branches, that are appropriate for this level of description, and to ensure that all steps are in the optimal order of performance.

2.4 Check level of description. Make sure that all steps are stated at approximately the same level of description.

3. Conduct any further analysis. For each step you have just identified, decide whether or not the action is at entry level for the lowest-ability learner in your target population of learners. If it is not at entry level, then recycle to Step 2 to further break it down.

- Assume that all necessary facts and concepts have been learned already. Just look at the action in each step.
- Take into account whether or not there will be a job aid available to the performer on the job.
- You may find it better to wait until you have done this step for all the steps you identified in Step 2, before recycling to Step 2 to further analyze any of them.
- Keep recycling through Steps 2 and 3 until all steps in the procedure have been broken down to entry level.

4. Describe task. Prepare a complete description of the task at entry level of description.

- This could take the form of a flowchart (see Figure 5.1 below), or it could take the form of a numbered list, such as that shown on page 5.9.
- Whenever a step is broken down into substeps, the substeps *replace* the step in the flowchart or list. Not all steps that were broken down will appear in the final description, only those that were not further broken down.

5. Identify all supporting content. Help the SME to identify all supporting content that an expert uses in performing the steps identified above.

5.1 Identify supporting content.

- The major kinds of supporting content include prerequisite concepts, information, understandings, thinking skills, and even attitudes and values.

5.2 Analyze the supporting content to entry level.

- For prerequisite concepts, use Steps 4 and 5 of the hierarchical analysis process (p. 4.4).
- For understandings, thinking skills, and attitudes/ values, you are on your own for now. (Sorry.)

Job Aid for Procedural Sequencing

1. **Prepare.**
   1.1 Establish rapport with SME.
   1.2 Identify characteristics of task in general.
   1.3 Identify characteristics of learners in general.
   1.4 Identify delivery constraints of task in general.

2. **Identify steps.**
   2.1 List and order about 3-9 steps.
   2.2 Identify any other ways the task is done.
   2.3 Check the steps for completeness and optimal order.
   2.4 Make sure all steps are at the same level of description.

3. **Conduct further analysis,** down to entry level (using Step 2).

4. **Prepare an entry-level description** of the entire task.

5. **Identify all supporting content.**
   5.1 Identify requisite information, understandings, skills, and affective qualities.
   5.2 Analyze those understandings, skills, & affective qualities to entry level.

Process Example 1: Mathematics

By Dan Kennedy

This example uses a task that was used in an example for hierarchical analysis and sequencing: **solving multiple-step equations in one variable**. The result of this analysis process appears after this.

1. Prepare

For the design of this sequence I served as the SME as well as the designer. For the sake of credibilty, I conducted formative evaluations throughout the process by soliciting input from other math teachers. The task of solving an equation is characterized by various levels of task description which range from very simple to quite complexa series of sequential steps, so it lends itself well to the procedural sequence.

The learners are 7th, 8th, and 9th graders, the same as I described in Chapter 4 (see p. 4.6). And 45-minute learning episodes were again selected.

2. Identify steps

In reviewing the job aid on the previous page, I set about to write down about 3-9 steps for solving all multiple-step equations in one variable. This is what I ended up with:

1. Are both sides of the equation simplified?
   If yes, go to step 3. If no, go to step 2.
2. Simplify each side of the equation.
3. Are there like-terms on opposite sides of the equation?
   If no, go to step 5. If yes, go to step 4.
4. Combine like-terms that are on opposite sides of the equation.
5. Does the variable term have a coefficient?
   If yes, go to step 6. If no, end.
6. Clear the coefficient.

Then I tried to think if there were any other ways that I sometimes did the task, but I couldn't think of any. I also checked to make sure I hadn't left out any steps—that these six would always be enough to solve multiple-step equations in one variable. Finally, I checked to see if the steps were all at the same level of description. Although the decision steps are less complex than the other steps, all steps were described in as general terms as possible.

3. Conduct further analysis

Next, I checked the steps, one by one, to see if any of them needed to be broken down into substeps, or whether they were already at entry level for the learners. I felt that each decision step was already at entry level, and that whatever few problems my students might have would be cleared up once they learned the step that followed the decision step.

So I turned my attention to step 2 (simplify each side of the equation) and repeated the process in Step 2 to identify substeps for it. These were the results:

2.1 Are all products and quotients simplified on each side of the equation?
If yes, go to 2.6. If no, go to 2.2.
2.2 Are all products simplified on each side of the equation?
If yes, go to 2.4. If no go to 2.3.
2.3 Use multiplication to distribute "a" in a(x+b) to get ax+ab.
2.4 Are all divisions simplified on each side of the equation?
If yes, go to 2.6. If no, go to 2.5.
2.5 Use division to simplify (x+b)/a to get x/a + b/a.
2.6 Are all sums and differences simplified on each side of the equation?
If yes, go to step 3. If no, got to step 2.7.
2.7 Use addition or subtraction to simplify ax+bx to get (a+b)x.

Then I did the same for steps 4 and 6. The results are shown in the "Product Example 1" section below.

Next, I went back to steps 2.1 – 2.7 to see if any of them needed to be broken down further. I felt that with examples, they would all be fine for my students at this level of description. An inspection of steps 4.1 – 4.6 and 6.1 – 6.9 led to the same conclusion. So I felt no further analysis was needed.

4. Prepare an entry-level description of the task

The "Product Example 1" section below shows two ways of describing the entire task at entry level. For the first one, which is a verbal description, whenever a step was broken down, I replaced it with its substeps. For the second one, which is more visual, I arranged all the steps in the verbal description into a flowchart (see Figure 5.1).

5. Identify all supporting content

The most important kind of supporting content is prerequisite concepts that students have not yet learned. I identified these by using the "concept analysis" methodology described in Chapter 4 on p. 4.4. I went through the entry-level description of every step in the task and listed every concept that I thought my students might not know at the beginning of the instruction on that step. For example, when teaching the skill of isolating "x" in the equation

$$\frac{2}{3} x = -16$$

(step 6.8 in the procedure), the action of performing that task has the prerequisite concept of identifying the coefficient.

Certain concepts may be entry level only in that they were introduced earlier, in a simpler context that students may be unlikely to transfer. For example the concept of identifying a reciprocal (in step 6) is learned in the primary grades when the students are taught how to divide fractions by "multiplying by the reciprocal of the second fraction". But for this task they may not be able to identify the reciprocal of the coefficient of a variable term. "Reciprocal" in this context might be foreign to them. So it is necessary to include it here as a new concept in the supporting content.

Other supporting content includes information, understandings, thinking skills, and even attitudes and values. For this task I could think of no information that needs to be memorized. But there certainly are important understandings, so I again went through each step to identify any understandings. I identified a number of understandings related to why and when to perform certain actions (steps). For example, in step 2.3 I felt it was important for students to understand the distribution property. But my experience indicated that most understandings had been acquired by the students prior to this instruction. Ones not previously acquired are listed in the next section. Finally, I have not given much thought to thinking skills and attitudes, but I recognize that I should pay more explicit attention to them in this course. For now, I have not included any.

All the resulting supporting content is listed in the "Process Example" next.

Product Example 1: Mathematics

By Dan Kennedy

Here is the final result of conducting a procedural task analysis for **solving multiple-step equations in one variable**. The description of the task is at entry level, so all steps not at entry level have been replaced by their substeps that are at entry level.

1. Are both sides of the equation simplified?
   If yes, go to step 3. If no, go to step 2.

2.1 Are all products and quotients simplified on each side of the equation?
   If yes, go to 2.6. If no, go to 2.2.

2.2 Are all products simplified on each side of the equation?
   If yes, go to 2.4. If no go to 2.3.

2.3 Use multiplication to distribute "a" in a(x+b) to get ax+ab.

2.4 Are all divisions simplified on each side of the equation?
   If yes, go to 2.6. If no, go to 2.5.

2.5 Use division to simplify (x+b)/a to get x/a + b/a.

2.6 Are all sums and differences simplified on each side of the equation?
   If yes, go to step 3. If no, got to step 2.7.

2.7 Use addition or subtraction to simplify ax+bx to get (a+b)x.

3. Are there like-terms on opposite sides of the equation?
   If no, go to step 5. If yes, go to step 4.

4.1 Is there a constant on the left side of the equation?
   If yes, go to step 4.2. If no, go to step 4.4.

4.2 Add the opposite of the constant on the left to both sides of the equation.

4.3 Simplify both sides by combining the constants.

4.4 Is there a variable term on the right side of the equation?
   If yes, go to step 4.5. If no, go to step 5.

4.5 Add the opposite of the variable term on the right to both sides of the equation.

4.6 Simplify by combining variable terms.

5. Does the variable term have a coefficient?
   If yes, go to step 6. If no, end.

6.1 Is the variable term a fraction, such as y/6?
   If yes, go to step 6.2. If no, go to step 6.4.

6.2 Multiply both sides of the equation by the denominator of the fraction.

6.3 Simplify by performing the products. End.

6.4 Does the variable term have a coefficient other than positive 1?

If yes, go to step 6.5. If no, end.

6.5 Is the coefficient a fraction?
If yes, go to step 6.8. If no, go to step 6.6.

6.6 Divide both sides of the equation by the coefficient of the variable.

6.7 Simplify by performing the divisions. End.

6.8 Multiply both sides of the equation by the reciprocal of the coefficient of the variable.

6.9 Simplify both sides of the equation by performing the multiplications. End.

Figure 5.1 Flowchart (To Do)

Supporting content

For step 2:

Concepts: **Like-terms, simplified products, simplified quotients.**
Principles: Distribution property, *** [More needed here.]

For step 4:

Concepts: Constants, variable terms.
Principles: The addition property of equality.

For step 6:

Concepts: Coefficient, reciprocal.
Principles: The multiplicative inverse property.

General

Principle: Understand the relevance of "solving multiple-step equations in one variable" to everyday life.

Thinking skill: The ability to manipulate symbols (numerals and variables) on an abstract level.

Attitude: An interest in the language of mathematics and a desire to use in every-day situations the skill of solving multiple-step equations in one variable.

Procedural Sequence Design Process

How to Do It

In one sentence, you design a procedural sequence by teaching steps in the order in which they are performed. In addition to that rule of thumb, you may find the following guidance helpful. The numbering of steps continues from the analysis process. In the next section, an example of this guidance process is provided, followed by an example of the resulting sequence. You may want to refer to these as you read through this guidance.

6. Select the size of a learning episode. Decide how big your groupings of content should be. We shall call each such grouping a "learning episode" in a course. (This is the same as for hierarchical sequence design.

- Analyze the delivery constraints of the specific instructional situation, if any. For example, you may be forced to use 45-minute time blocks for class sessions, with two hours of homework expected for each hour of class time. However, with enough effort, you may be able to use other options, in which case the standard practice is not a constraint, and you can make your decision based on more important considerations.
- Be sure to keep in mind both in-class and out-of-class 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.

7. Select an approach. ???***

8. Group and sequence the episodes. Using your decisions from Step 1, group the steps in your procedure into learning episodes, and arrange those episodes in order of performance.

- Keep in mind that the steps you group together should all be contiguous, in that they are all performed one right after the other.

9. Design a within-episode sequence. Design a within-episode sequence for each learning episode. This entails sequencing all the supporting content, as well.

- The steps should be arranged in the order in which they are performed.
- Each prerequisite concept should be taught immediately before the step for which it is prerequisite.
- Each understanding should generally be taught immediately prior to, or during, the step in which it is used.
- For thinking skills and attitudes/values, use your best intuition, and gather some formative data.

This completes the procedural sequence design process. An example of this process is described next.

<u>Job Aid for Procedural Sequence Design</u>

6. Decide on the size of a learning episode.
- Analyze the delivery constraints.
- Keep in mind both in-class and out-of-class time.
- Too big is bad.
- Too small is bad.

7. Select an approach. ???***

8. Group and sequence the episodes.
- Based on size and approach
- Teach no step before all its prior steps.

9. Design a within-episode sequence.
- Again, teach no step before all its prior steps.

Process Example 1: Mathematics

By Dan Kennedy

The following is an example of the process for designing a procedural sequence, using the guidance provided in the previous section. It is a continuation of the previous mathematics example: **solving multiple-step equations in one variable**.

1. Select the size of a learning episode. I selected 45-minute time blocks for the reasons I expressed in the example in Chapter 4.

2. Select an approach.

3. Group and sequence the episodes.

4. Design a within-episode sequence.

Product Example 1: Mathematics

By Dan Kennedy

Here is the final result of designing a procedural sequence for **solving multiple-step equations in one variable.**

Learning Episode	Steps	Supporting Content
1	1 Are both sides of the equation simplified? 2.1 Are all products and quotients simplified on each side of the equation? 2.2 Are all products simplified on each side of the equation? 2.3 Use multiplication to distribute “a” in a(x+b) to get ax+ab.	Like-terms Simplified products Simplified quotients Distribution property
2	2.4 Are all divisions simplified on each side of the equation? 2.5 Use division to simplify (x+b)/a to get x/a + b/a.	
3	2.6 Are all sums and differences simplified on each side of the equation? 2.7 Use addition or subtraction to simplify ax+bx to get (a+b)x.	
4	Review steps 1-2	
5	Quiz on steps 1-2	
6	3 Are there like-terms on opposite sides of the equation? 4.1 Is there a constant on the left side of the equation? 4.2 Add the opposite of the constant on the left to both sides of the equation. 4.3 Simplify both sides by combining the constants.	Constant
7	4.4 Is there a variable term on the right side of the equation? 4.5 Add the opposite of the variable term on the right to both sides of the equation. 4.6 Simplify by combining variable terms.	Variable term
8	Review steps 1-4	
9	Quiz on steps 1-4	
10	5 Does the variable term have a coefficient? 6.1 Is the variable term a fraction, such as y/6? 6.2 Multiply both sides of the equation by the denominator of the fraction. 6.3 Simplify by performing the products. End.	

11	6.4 Does the variable term have a coefficient other than positive 1? 6.5 Is the coefficient a fraction? 6.6 Divide both sides of the equation by the coefficient of the variable. 6.7 Simplify by performing the divisions. End.	Coefficient
12	6.8 Multiply both sides of the equation by the reciprocal of the coefficient of the variable. 6.9 Simplify both sides of the equation by performing the multiplications. End.	Reciprocal
13	Review steps 1-6	
14	Quiz on steps 1-6	
15	Test on steps 1-6	

Figure 5.2 A sequence outline for a skill in mathematics.

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 procedural analysis and sequence design. Here are the criteria.

The Problem

- The procedure should be relatively simple. Picking a more complex one will just make your project take longer, without enhancing your learning much. To keep it simple, think in terms of a procedure that will take no longer than 15 minutes to perform, and about 10-30 hours to learn. It may be a mental procedure, a physical procedure, or a combination of the two.
- 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

The following problem and scenario are offered for those cases in which the readers are having difficulty choosing their own.

*** (To be completed.)

What's Next?

Given this chapter's skill-building focus on how to design, and conduct analyses for, procedural sequences, Chapters 6-8 provide similar guidance for the other three major sequencing strategies: simplifying conditions, conceptual elaboration, and theoretical elaboration. Those chapters can be approached in any order, but be sure you have a good understanding of a sequence from Chapter 3 before you go to its corresponding skill-focused chapter.

References

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