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Strategies and Techniques for Designers, Developers, and Managers of eLearning

THIS WEEK — DESIGN TECHNIQUES

Last Things First: The Power of Backward Chaining

BY BILL BRANDON

Everyone has heard of the "learning curve," but simply producing e-Learning that efficiently helps learners up that slippery slope isn't good enough. To be effective, e-Learning must also defeat the learning curve's evil twin, the "forgetting curve." And it's not like the forgetting curve waits politely to start its work until after the e-Learning is over — forgetting starts as soon as learning begins.

In many situations in workplace settings and in education, we develop e-Learning to teach people how to successfully complete long sequences of actions required for specific tasks. Usually the process is to teach how to start the task sequence and then we proceed right along to the end of the chain of events. But have you noticed when you do this that:

- People learn the first steps better than the last steps?
- People have trouble remembering the last elements, and they get things "mixed up" in the middle of the sequence?
- People make more mistakes the further they go in the e-Learning?
- People get bored by the level of detail presented, discouraged because they keep "screwing up," or want to quit in frustration because they aren't able to make progress quickly?

When a learning progression is long, it becomes much more difficult for learners to add new steps. Many activities have to be completed before a new step can be added. It takes the learner a long time to be able to produce the final result. The forgetting curve does its best (worst?) work here. Sooner or later the cumulative

Continued on next page

Learners face two challenges: learning and forgetting. Designs for e-Learning tend to concentrate on making learning efficient. There is a simple technique for making sure that e-Learning also reduces forgetting, and this article explains what it is and when to use it. This expert approach can make your e-Learning truly memorable!

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As in any profession, there are many different perspectives about the best strategies, techniques and tools one can employ to accomplish a specific objective. This **Journal** will share these different perspectives and does not position any one as "the right way," but rather we position each article as "one of the right ways" for accomplishing a goal. We assume that readers will evaluate the merits of each article and use the ideas they contain in a manner appropriate for their specific situation. We encourage discussion and debate about articles and provide an Online Discussion board for each article.

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memory load, forgetting, and mistakes interfere with learning, and e-Learning becomes less efficient and effective.

There is another, better, way to order many of your teaching progressions to avoid these problems and to banish the evil twin.

In this article, I will introduce you to this better alternative, backward chaining. You will read about instructional sequencing principles and effects, and you will see one very simple example. The simple example will demonstrate basic task analysis and "chunking" the results in a fashion that reduces forgetting. I will give you some guidelines so that you will be able to tell when you have a task that can be taught more successfully using backward chaining. And, most importantly, I'll explain the series of steps that many designers use to assemble backward-chained instruction.

Forward and backward learning progressions compared

We are used to seeing learning progressions presented in "chronological" or task order: the sequence starts at the beginning and proceeds to the finish. This is the standard for classroom delivery, textbooks, and videos. This task order has become the default for e-Learning, too. Most people, including Subject Matter Experts (SMEs) just assume that the logical start-to-finish progression is the best way to go about any teaching or learning task.

If an e-Learning progression is set up start-to-finish, in task order, it is using "forward chaining." If set up to teach the last part of the skill first, the progression is called "backward chaining." (I wrote at length about learning progressions in the December 16, 2002 issue of **The Journal**, "How to Build Composite Learning Progressions Using Approximations." You may find it useful to review that article if the topics of task analysis and learning progressions are new to you.)

Problems with forward chaining

In addition to the problems with forgetting already mentioned, forward chaining sparks some undesirable learner behaviors as the skill being taught gets more complex. For example, learners may create a "mental checklist" so that they can be sure their technique is correct and that they are doing all the steps. Other learners may create mental roadmaps or come up with mnemonics to help them remember everything they are supposed to do, in the right order. In fact what any of these practices do is to make cognitive control part of what should be "covert" or unconscious behavior as the learner executes the skill. This almost always makes the skill performance less effective because of the memory load involved, and because of the time it takes to use the mental checklist. And of course, if the checklist, roadmap, or mnemonic are badly formed or incorrectly recalled, the performance may turn into a disaster.

Still more problems with forward chaining spring from increased learner anxiety associated with this strategy. Negative self-appraisals increase as the number of errors increase. The effect of this negative self-talk is serious and real. What an evaluator sees is that skills are executed well during the start of instruction, but they deteriorate as the sequence continues. I believe that, in some cases, this may be a significant factor in the high rate of abandonment noted by others in e-Learning.

What is backward chaining?

Backward chaining is formally defined as "the strategy of teaching tasks in reverse of the order in which they are

Backward chaining may be ideal for applications where the final product is the result of a linear, heavily cumulative sequence of tasks. These are tasks that tend to be done the same way every time and relate to what Ruth Clark and others refer to as "near-transfer."

done on the job." In many situations, this is more effective than using the default sequence (forward chaining) and avoids common training problems. Systematic use of backward chaining will result in learning designs that:

- Keep instructional input or presentation to a minimum, reducing demands on the learner's short-term or working memory
- Facilitate transfer of procedural information to long-term memory
- Keep learners involved and challenged
- Enable learners to successfully complete a task early in the progression
- Can be repurposed for use in any medium or method of presentation

Backward chaining may be ideal for applications where the final product is the result of a linear, heavily cumulative sequence of tasks. These are tasks that tend to be done the same way every time and relate to what Ruth Clark and others refer to as "near-transfer." Such tasks are common in the use of most computer software, in many processes at work, and in many educational situations from kindergarten through graduate school.

Additional criteria for when to use backward chaining appear later in this article. But let's get down to cases for a minute.

A basic example of backward chaining. Anyone want a cookie?

When my daughters were small, they loved to bake cookies. They learned how in a way that was totally opposite to the way everyone learns in school, yet it was totally natural. In fact, I'll bet that readers with children taught their kids quite a few things in exactly the way we taught our girls to make chocolate chip cookies from scratch.

In school, you always start with the beginning. The textbooks always show a sequence of pictures that begins with the first step. We taught Valerie and Jessie to do things backwards, at least as compared to the school standard. The first thing they learned was how to safely take cookies out of the oven, wait until they were cool, and put them in the cookie jar (with a small "cookie toll" being collected along the way). The next thing they learned was how to safely put the sheet of cookies into the oven, how to set the timer, and how to tell when the cookies were ready. Then they took the cookies out and put them in the jar (with the usual toll). Each time we made cookies, the girls added a step closer to the start, until eventually they were able to start by gathering the ingredients and tools, and to complete the entire process under the watchful eye of one parent or the other.

This example, simple though it is, illustrates the basic way in which backward chaining works. To understand it better, let's upgrade the cookie-baking to a course given in an educational setting.

The cookie curriculum. As part of the development of the cookie curriculum, a team of experts analyzed the task of making cookies. (See Figure 1, below.) They decided that all of the many details involved in making cookies could be reduced to seven essential steps, which can be further combined into three groups. The groupings they arrived at are discrete "chunks" that can be taught in a single module. The chunks are of such a size that the learner can easily feel connected to the actual task itself, and never lose sight of the fact that the reason for learning all of this is to make cookies. The resulting chart actually provides a basic domain theory; that is, it would apply to the making of many, if not all, types of cookies. In this case, the outcome is chocolate chip cookies.

You can see that there are at least two logical orders in which to teach this whole task. You can start with preparing the ingredients and conclude with the baking. Or you can start with the baking and conclude with preparation of ingredients. For the purposes of this article we'll ignore the other possibilities (start with arranging the workstation and concluding either with ingredients or with baking). The alternatives are sometimes useful, but in this case they would just complicate the problem of the next step in designing the cookie curriculum, which is sequencing the instruction.

The designer decided to use backward chaining as the sequence for the basic course (the complete curriculum also includes a course on decorating cookies, for example). The progression the designer created is summarized in Figure 2 on page 4. It is important to recognize that in both Modules 2 and 3, the learner will complete the task by baking a batch of cookies. It is also possible for the designer to decide to cover "Measurement" as a short introduction to Module 3, rather than all the way at the beginning of the course. Measurement could also be addressed in another course, or as a course of its own. To keep the progression simple for this example, I elected to show all pre-requisites grouped at the beginning of the course. Usually, you would prefer to address important skills like measurement closer to the point in the progression where they will actually be used.

The final step the designer performed was to set up the exercises in each of

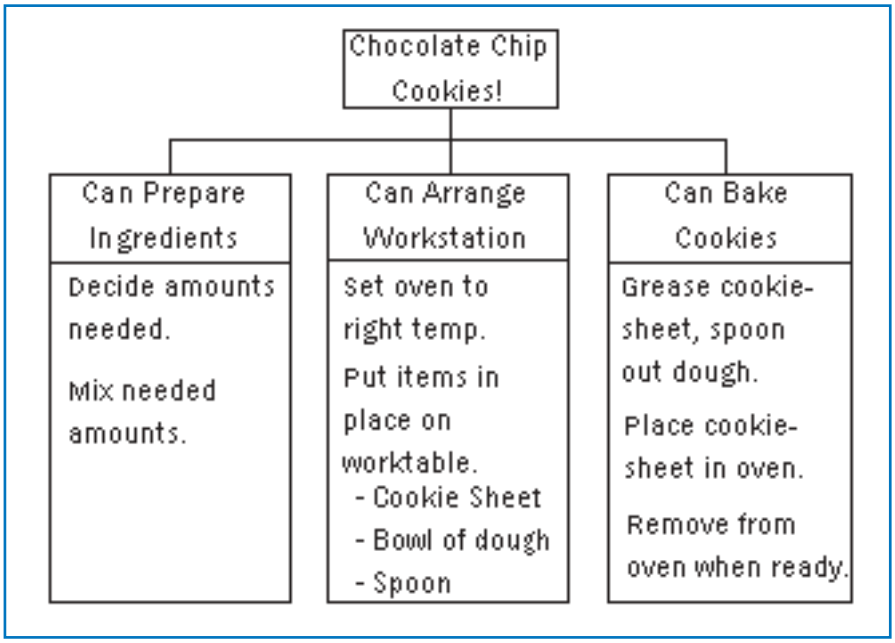

FIGURE 1 *The experts' view of cookie production*

the modules. Figure 3, below, shows one way to do this, using learning theory borrowed from a number of sources. Without getting lost in the details that will be covered later, notice that Module 3 includes four exercises. In the first exercise, learners are provided with precomputed ingredient amounts, which they then mix. At the end of the fourth exercise, the learners set up their work station and bake the cookies (this has been summarized as "Produce a batch of cookies"). Subsequent classes of would-be pastry chefs in Modules 1 and 2 can use all those mixed ingredients from the first three exercises. Presumably it is no problem to dispose of all the cookies produced.

How backward chaining fixes learning problems

The biggest advantage to backward chaining from the learner's point of view is that it offers immediate satisfaction. The learner completes the activity in every exercise or module. The step sizes minimize mistakes and this makes for higher probability of success. Unlike forward chaining, backward chaining steadily increases skill strength instead of letting interference degrade the skill elements that have already been taught.

Interference does not occur because the learner is always "working into" and practicing elements that have already been done with success. This allows the learner to put undivided attention on the new content.

In addition, the learner feels less tension or anxiety because the task and its steps are "chunked" in a way that keeps them simple. The learner always has a clear understanding about what to do next. Finally, because the first thing the learner experiences is a successful outcome, it is easier for the learner to visualize and anticipate success. This increases learner confidence and further raises the probability of success.

Studies done years ago showed that backward chaining is superior in developing speed, accuracy, fluency, and skill maintenance. Subjectively, my experience with backward chaining is that learning takes place faster, learners develop greater confidence, and performance is generally better on the job. In

INTRODUCTION AND OVERVIEW	TEACHING SEQUENCE (Exercises in Modules)			CRITERION CHECK (Verification)
What will be taught Why it will be taught Theory as needed Measurement Safety Precautions	Module 1 Baking Cookies	Module 2 Setting Up Workstation (Produce a batch of cookies)	Module 3 Preparing the Ingredients (Produce a batch of cookies)	Prepare cookies from scratch ingredients, without assistance, in 60 minutes. Appearance, taste standards.

FIGURE 2 *Overview of the cookie curriculum*

Module 3: Preparing Ingredients *(Given: Number of cookies to prepare)*

Exercise	DEMONSTRATE	PROMPT	RELEASE
1	Mix needed amount of ingredients	--	Produce a batch of cookies
2	Compute needed amount of ingredients	Mix needed amount of ingredients	Produce a batch of cookies
3	--	Compute needed amount of ingredients	Mix needed amount of ingredients and produce a batch of cookies
4	--	--	Compute & mix ingredients, produce a batch of cookies

FIGURE 3 *Exercise design for Module 3 of the cookie curriculum*

addition, if a learner quits early, the chances are better that he or she stopped because the backward progression arrived at the level of task elements they had already mastered. In my opinion, backward chaining should at least be considered seriously whenever designing e-Learning to teach progressions or sequences of skills and behavior.

Applications of backward chaining. Backward chaining has a long history of use in teaching a broad range of skills. It has been used to teach children to tie their shoes and it has been used to teach graduate students to perform analysis of variance and other complex statistical computations. It has been used to teach basic skills in writing in primary and secondary schools, job skills to factory workers, and complex emergency response procedures to military personnel.

When to use backward chaining. Earlier, I mentioned that backward chaining is best suited to near-transfer training: situations in which the task is basically done the same way every time. Backward chaining may not be as suitable for use when learners are required to use judgment to vary the steps of a procedure. However, these statements are also true for forward chaining.

There are four specific situations when backward chaining is preferable to forward chaining:

- When completion of the task provides natural reinforcement for the learner;
- When "escaping" from instruction would motivate the learner;
- When the learner has mastered less than half of the steps in the task chain OR when the learner is close to already having acquired the steps near the end of the chain;
- When the learners are less patient or less inclined to be cooperative.

How do you set up a progression with backward chaining?

Suppose a task to be performed consists of these steps:

Start —> Step 1 —> Step 2 —> Output

At the risk of repeating myself too much, look again at the options for teaching this task in terms of the point at which the learner produces output. The conventional approach, or forward chaining, is to teach the steps in the order in which they are done on the job. The learner only produces the task output in the last exercise.

In backward chaining, the exercises are ordered so that learners produce output *right away*. For example, the learner is presented with a nearly completed task, such as a letter on screen that is already typed, spell-checked, edited, and formatted. The learner is immediately shown the steps needed to print the letter, finishing the job. The next exercise will demonstrate how to format text that has been typed, spell-checked, and edited, and the learner will be prompted or coached through the steps needed to print it. The third exercise demonstrates editing, prompts formatting, and releases the learner to print the text without further help. These steps are repeated until the learner can do the whole task unassisted.

Overview of steps

Because backward chaining always seems somewhat counter-intuitive to designers the first time they see it, the specific design process involved may also feel a little "un-natural." Fortunately, there are only four steps in the process,

and they are straightforward and simple.

Before starting the development, as always, you need to have decided what performance will be taught (in other words, you need to have decided on your objectives). You also need to have decided who will be taught (the target audience), and how the instruction could be presented. This last decision involves thinking about synchronous delivery vs. asynchronous delivery and the possibility of blended learning. It also involves thinking about the appropriate use of multimedia and text.

Describe the job. This can take a little time, but it is important to do it right. The success of any e-Learning application rests on the quality of the description and analysis of the task or skill being taught. Remember that countless studies have shown that, when determining success, the medium of delivery (e-Learning, classroom, plain text) matters less than the quality of design.

In this step, you are going to identify, organize, and describe in measurable terms all conceivable situations that signal the start of, or that arise from, the performance, and all mastery level actions that lead to the desired results or goals. As you will see, the result may look as simple as Figure 1 did.

In doing the task analysis, begin with the fewest number of steps. Dividing a skill into smaller and smaller steps moves the learner further and further from the purpose of the activity. If there are steps that turn out to present problems, you can always break them down further later on.

Task analysis must include both steps that can be seen (motor skills) and those that cannot be easily observed (thinking, analysis, judgment). Test the scope of the task analysis by asking if the learner will be able to complete the task in a reasonable amount of time, and will the learner know:

- When to begin the task
- How to prepare for the task
- How to determine if the task has been done well
- What to do if a problem comes up
- What to do at the end of the task

If the answer to any of these is "no," then the task analysis needs further work before you continue with the design of the instruction.

Group the tasks. Organize the tasks into spans of learning activities. Each span should be the largest gain toward mastery that learners can make successfully. You want to come up with the smallest number of these spans that you can. Think in terms of "elegance" rather than "complexity" or "dumbing down." At this point, I like to show my groupings to expert performers and to clueless beginners, as well as to other designers. With the right questions to each group to elicit feedback, I can find out pretty quickly whether my groupings are the appropriate size.

Sequence the instruction. The basic principle is to make sure that learners reach the goal or produce the desired outcome early. They should produce the desired outcome in every exercise or at least in every module of an e-Learning application. Over the whole application, the span of the learner's activity will increase with each exercise until it includes the entire task. If in doubt, refer to figure 3 again.

Construct the exercises. Finally, you are ready to design the actual exercises. You may choose to be very thorough, as in Figure 3, or you may find it sufficient to show the learner what to do and then release them to do it on their own.

An exercise is a sequence of steps, each one of which provides a graduated level of help to move the learner toward mastery of the task. There are three levels of help that provide this support: demonstrate (sometimes called priming), prompt, and release (sometimes called performing).

In the context of Figure 3 and exercise construction, "demonstrate" can simply mean that the e-Learning application shows the learner what to do, through instructions or examples. It can also mean that the e-Learning application tells the learner what to do one little step at a time and the learner does each step immediately afterward. In either case the learner receives instructional aid from the e-Learning system to guide performance to a successful conclusion.

"Prompt" means that the e-Learning system provides hints or helps as needed by the learner. These helps can be in the form of partial hints or completely worked out examples. The system can do part of the work for the learner by providing partly worked out exercises, multiple choice questions, or pictures. Or

EXERCISE	DEMO	PROMPT	RELEASE
1	STEP 3	(NONE)	(NONE)
2	STEP 2	STEP 3	(NONE)
3	STEP 1	STEP 2	STEP 3
4	(NONE)	STEP 1	STEPS 2,3
5	(NONE)	(NONE)	ALL STEPS

FIGURE 4 *Example of sequencing exercises for a three-step task element*

the helps can be "memory joggers," such as mnemonics or examples. This step can often be skipped, especially if it seems to be dumbing down the instruction or prolonging it unnecessarily. You have to know your audience and judge accordingly.

"Release" means that the learner does the task without any help from the e-Learning application. This is the step where transfer to long-term memory and to the job begins.

You will need to sequence the exercises using these levels. Figure 4, on page 6, provides a general plan for teaching a task element that has three steps. Remember, if the plan in Figure 4 results in a sequence that is too tedious or boring for the learners, or one that insults the learners' intelligence reduce and simplify to obtain a better experience for the learners.

What happens next

After you have developed the sequence and the exercises, you are in a better position to identify the overview and theory items learners will need. These items support the learner during the instruction and also support more generalized performance of the task back on the job.

At this point, you are ready to begin development of the e-Learning itself. If your organization uses storyboards, you have a very good basis for creating them. For simple e-Learning applications, the sequence and exercise designs may be sufficient if the designer is also doing the development. In any case, I recommend trying out the e-Learning through alpha and beta testing and making necessary adjustments before release.

Summary

When I teach instructional designers how to use backward chaining, the content of this article is the introduction and overview. The rest of the instruction is delivered as a backward chain, beginning with construction of exercises to deliver instruction for a job that has been described, grouped, and sequenced. This procedure works whether the delivery of my instruction to the designers is done in a classroom, in one-on-one coaching, or as an e-Learning application.

In this article, I have chosen not to go that far. Mainly this is in the interest of

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space, but it is also because the range of content suited to backward chaining is so vast that no one example would be a helpful illustration for every Guild member. I am happy to field simple questions by email, however.

You will find that backward chaining is useful whether your philosophical orientation tends toward the behavioral school or toward the cognitive school. It's mainly a matter of choosing a sequence that keeps the forgetting curve in check, while advancing the learning curve. I hope you enjoy using this powerful tool in your e-Learning designs!

AUTHOR CONTACT

Bill Brandon is the editor of **The eLearning Developers' Journal**. He has been designing, delivering, and managing learning and training activities including e-Learning since 1968, in settings ranging from shipboard to corporation boardrooms. Bill is a past president of the former Texas Chapter of ISPI, has done postgraduate work in Human Behavior and is the author or co-author of numerous books and magazine articles on technical and training topics. You can contact Bill by email at bill@elearningguild.net.

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