BERKELEY LAB
Bringing Science Solutions to the World

Berkeley Lab Training

Creating Effective Training

Whitepaper

Background

Berkeley Lab Training is a formal program within the Environment/Health/Safety Division of Lawrence Berkeley National Laboratory. Berkeley Lab Training provides instructional design, video and graphics production, e-learning, instructor-led, and practical course design and development, as well as produces performance support job aids. Berkeley Lab Training is responsible for developing and maintaining 80% of the Lab's training requirements which equates to ~30,000 training completions annually for the 6,000 staff and visiting researchers that perform work at Berkeley Lab.

Berkeley Lab Training actively contributes to the UC System Wide Training and Education Working Group and the Department of Energy EFCOG Training Working Group. The Berkeley Lab Training Program is described in Berkeley Lab's EHS Manual https://www2.lbl.gov/ehs/pub3000/CH24.html

This white paper describes our approach to instructional design as applied to formal Berkeley Lab Training development. These principles have been applied to most of our training development projects within the last two years. That said, it is not applicable to all of our projects which range from general hazard awareness-level training/communications, to informative instructional videos, both of which are focused on demonstrating and explaining and do not involve practice.

Topics

- How memory informs design
- Design principles
- Design methodology

You Have to Do Work to Remember What You Learn

Imagine you need to hire someone and two candidates show up for interviews. One has never performed the task, but he's read a book about it and listened to an expert speak about it. The other candidate has done similar work in her previous job. Which candidate are you more likely to hire?

Most people choose the person who has previous work experience, because experience is usually a more effective proxy for competence than "book learning." Yet, many courses that are designed to teach someone an important safety (or other) skill end up falling back on one particular delivery method: the lecture. Essentially, these courses try to instill competence in students using the least effective means: having them listen to an expert.

While telling people information is often necessary, it has several weaknesses as a primary instructional strategy. If you're just telling people things and not having them use that information to make decisions or take actions, then the information enters their short-term memories and is quickly forgotten:

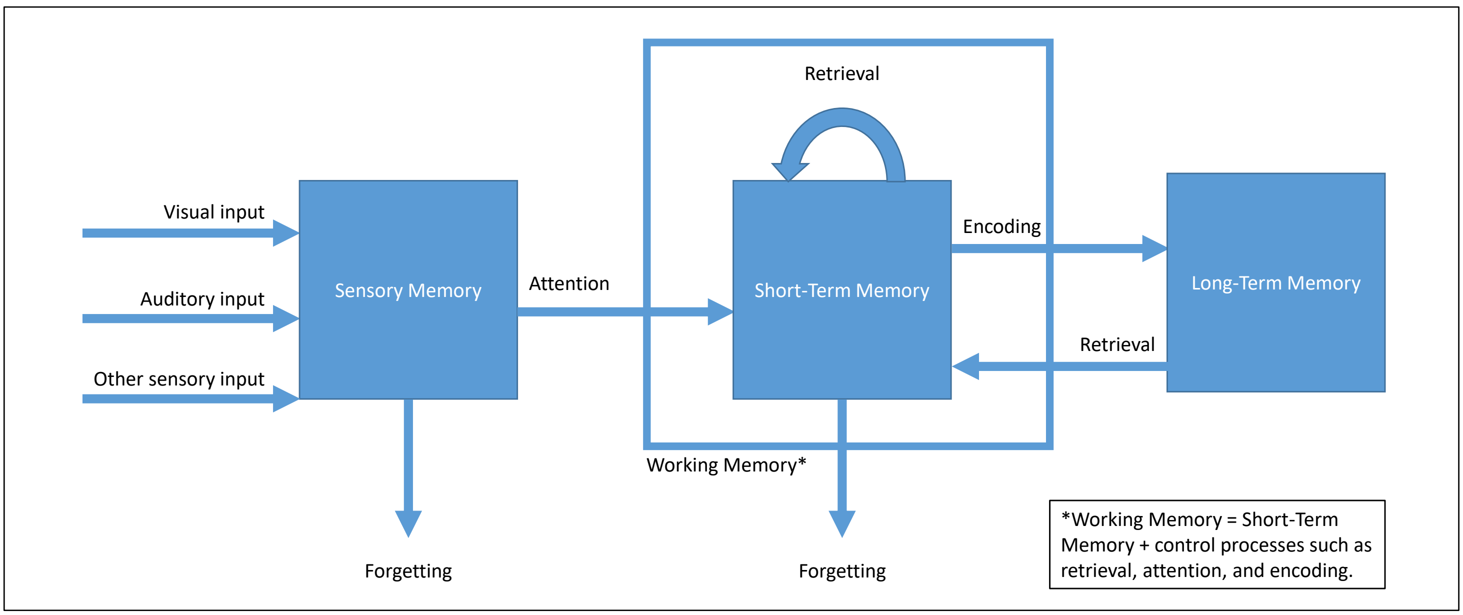

Figure 1: The Multi-Store Model of Memory[1]

Forgetting is the default outcome! The diagram in **Figure 1** shows a common model of human memory. Sensory input is constantly entering our sensory memory, but we forget everything that comes in unless we specifically pay attention to it. When we pay attention to some sensory input—a classroom lecture, for example—that information enters our short-term memories. There it is again quickly forgotten unless we actively take steps to remember it. If you've ever tried to remember a phone number long enough to dial it, you know that you will forget it quickly unless you constantly say it back to yourself (or silently rehearse it over and over again in your mind). This is because retrieval keeps the information from fading out of

[1] Diagram loosely adapted and elaborated from Atkinson, R.C. & Shiffrin, R.M. (1968) Human memory: A proposed system and its control processes. In K.W. Spence and J.T. Spence (Eds.), *The psychology of learning and motivation, vol. 8*. London: Academic Press.

short-term memory. In fact, if you do enough retrieval, that information will be encoded into your long-term memory. If you don't do enough retrieval, you will probably forget that phone number by the time your conversation ends.

What this means is that *students have to work with the material they are learning* in order to encode it into long-term memory. The act of recalling information from memory is critical to this encoding process[2]. One reason that we ask learners to answer questions, solve problems, or analyze situations, is because this creates the need for them to recall the relevant supporting information over and over again, and this helps solidify that information into their long-term memories.

Design Principles

This biological need to work with material in order to remember it drives us to reject "telling" as our primary design strategy. Instead, Berkeley Lab Training designs courses with the following four principles in mind:

1. Jumpstart learner practice
2. Practice skills in context
3. Prioritize actions over memorization
4. Isolate, then integrate

1: Jumpstart Learner Practice

Driving learner practice is the first and most important principle because research shows that repeated practice improves performance[3]. In e-learning courses, learners generally practice in simulation. Research shows that practice in simulation is more effective than a lecture[4].

However, since a training course is often a one-time event, there's not enough time in a typical course to have students practice a skill over and over again until they are fluent. We *can* get them started, though, by requiring students to perform the first few practice sessions in the course. On-the-job training continues to drive learner practice, and the learner will then perform this skill as part of his or her job. That continued on-the-job practice will solidify the skill and get the person to fluency.

[2] Karpicke, J. D., & Roediger, H. L. (2008). The critical importance of retrieval for learning. *Science, 319*, 966-968
[3] Begg, Colin B., Cramer, Laura D., Hoskins, William J., & Brennan, Murray F. (1998). Impact of Hospital Volume on Operative Mortality for Major Cancer Surgery; *Journal of the American Medical Association. Vol. 280, No. 20,* 1747-1751.
[4] *Matsumoto ED, Hamstra SJ, Radomski SB, Cusimano MD. The effect of bench model fidelity on endourological skills: a randomised controlled study. J Urol 2002;167 (3):1243–7.*

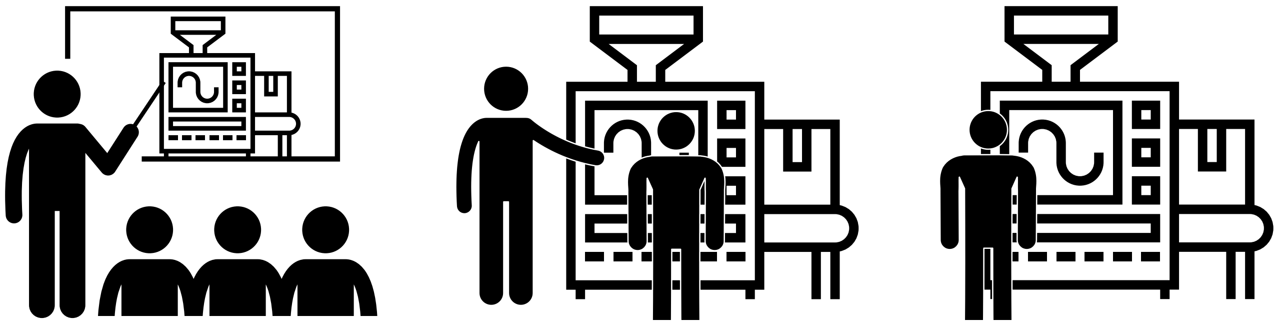

Figure 2: Formal training (classroom or e-learning) is the* start *of the process, not the end.

Note that if learners' jobs do *not* require them to perform the skills they learn in class, it will be difficult for the class to have much impact. Learners will quickly forget skills they don't use regularly. We recommend creating performance support instead of training for tasks that learners perform infrequently.

2: Practice Skills in Context

This principle is an important qualification on *how* we implement the first principle. We want the context in which the learner practices to be as similar as possible to the context in which the learner will actually perform in the real world. This is because we know from peer-reviewed research that when the learning context matches the performance context, performance is improved[5,6]. If you want to learn how to drive a fork lift, you'll learn best by training on a fork lift (or in a fork lift simulator) as opposed to learning to drive some other kind of vehicle and hoping the skills transfer.

Often the basis for practice involves solving work-relevant problems that allow learners to make and then correct mistakes through reasoned feedback. Providing practice within work-relevant context and prioritizing problem-centered instruction over content-oriented instruction is supported by the principles of adult learning theory[7].

The principle of practicing skills in context, drives us to ask our subject-matter experts to take us on location to job sites so we can understand the full context in which our students will be required to perform. We'll want to take photos of the sites, and of typical equipment learners use. We often work directly with experienced staff who perform the work. This is necessary so that we can build practice challenges for learners that closely reflect the work challenges we ultimately need them to solve.

3: Prioritize Actions Over Memorization

In practical terms, people's *actions* are a greater determinant of their safety than their *knowledge*. Most

[5] D. R. Godden & A. D. Badderley; Context-Dependent Memory in Two Natural Environments: On Land and Underwater; *British Journal of Physchology;* (1975), 66, pp. 325-331

[6] Steven M. Smith; Background Music and Context-Dependent Memory; American Journal of Psychology, Vol. 98, No. 4, Winter 1985, pp. 591-603

[7] See, for example, http://www.instructionaldesign.org/theories/andragogy/

people who get shocked are perfectly aware that electricity is dangerous. But they still get shocked—not because of a lack of knowledge of the hazard, but because they failed to put this knowledge into action by following safe work practices. Knowledge alone does not keep anyone safe; acting on that knowledge does. Knowledge only becomes useful when it informs actions or decisions, so this principle reminds us to focus our courses on getting people to make safe decisions and take safe actions, not just memorize facts.

To be instructionally effective in a short amount of time, we may have to cover less content. We focus on those *decisions* and *actions* that will have the greatest impact and we try to make sure learners have enough time to practice making those decisions and taking those actions in response to realistic challenges. Research also shows that adding in non-essential, "nice-to-know" information actually *reduces* learners' ability to retain the essential teachings from the course[8]. This process of focusing and prioritizing can at times be a challenge when working with clients who value information specific to their programs or disciplines which does not directly influence behaviors. We manage this by first agreeing on core performance objectives, and by educating clients in our process. When the client states "It's important that they know about…." We follow up by asking how this will help our students make safe work decisions. By prioritizing actions, we also prioritize the knowledge that supports those actions, and deprioritize knowledge that does not inform actions or decisions. For "knowing" to be necessary, it must be necessary for "doing."

4: Isolate, Then Integrate

Working memory is extremely limited. Only a small number of "things" can be in working memory at one time.

However, the size and scope of each "thing" is nearly unlimited. For example, a 10-step procedure, like inspecting your insulated gloves for damage prior to use can be chunked as a single step in a larger procedure if you've already learned how to inspect your gloves to "automaticity" (meaning, you can do it automatically, without having to think too much about it)[9]. The same is true for inspecting a volt meter prior to use. This may have ten steps that through practice become automatic. So in order to effectively teach complex skills, we sometimes need to first isolate the sub-skills. We get learners to master those in isolation, and only then integrate them together into the larger, fuller task. We teach students how to inspect their gloves, inspect their meters, and choose their tools as isolated modules at first, but later in the course we integrate them into larger challenges that require students to practice the skills together so that the students can master the combination as part of a routinized practice that for this example could be called "work preparedness."

Design Methodology

We need methods and techniques to help us design training that adheres to the four principles of:

- Jumpstarting learner practice
- Practicing skills in context

[8] Harp, Shannon F., & Mayer, Richard E. (1998). How Seductive Details Do Their Damage: A Theory of Cognitive Interest in Science Learning. *Journal of Educational Psychology, Vol. 90, No. 3,* 413-434.
[9] Sweller, J. et. al. (1998) 'Cognitive Architecture and Instructional Design,' *Educational Psychology Review*, Volume 10, Issue 3, September 1998.

- Prioritizing actions over memorization
- Isolating, then integrating

Here are a few techniques we use:

1. Start with Action-Oriented Learning Objectives

In 1956, Benjamin Bloom published[10] the first version of what has come to be known as **Bloom's Taxonomy**. A revised version[11] was published in 2001, and the discussion here uses the revised version.

Bloom's Taxonomy organizes the entire cognitive domain of knowledge into ascending levels of sophistication, beginning with **Remembering** at the bottom, and rising up through **Understanding**, **Applying**, **Analyzing**, and **Evaluating**, to **Creating** at the top level. The taxonomy is usually visualized as a pyramid:

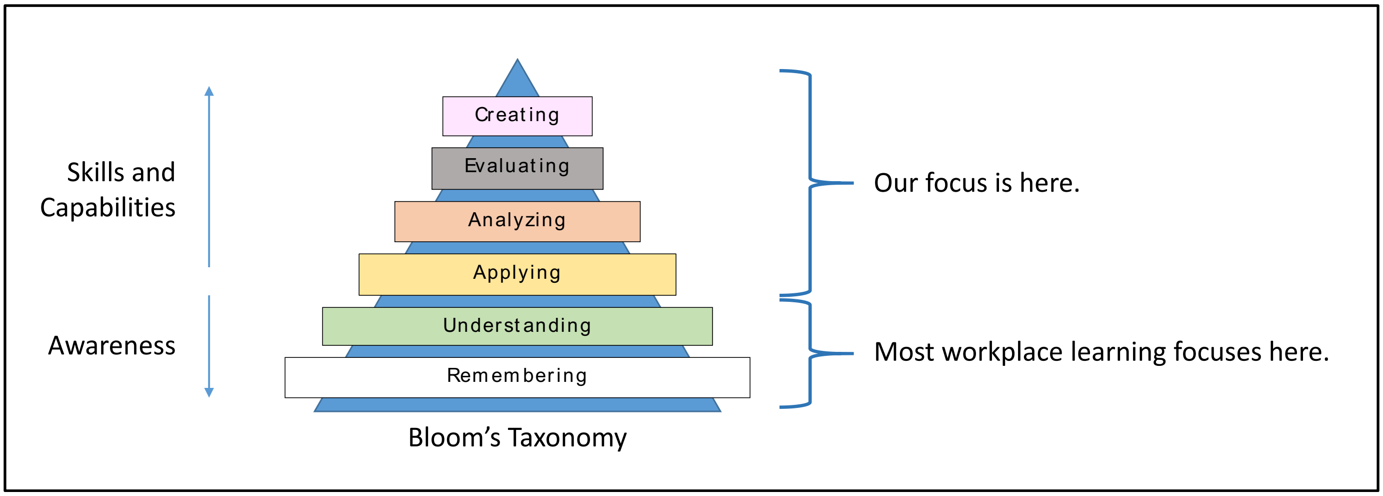

Figure 4: Bloom's Taxonomy

A great deal of workplace training is aimed at the bottom two levels on Bloom's: **Remembering** and **Understanding**. This is why so much training you take in the workplace ends up being little more than a dump of information, followed by some multiple choice questions that "test" if you can remember what the course or instructor just told you. These courses treat the learner as a passive receiver of information. At best, such courses can only hope to give the learner a general awareness of the topic.

Ideally, when we create a course, it is because the Lab has identified specific skills gaps that are affecting safety. We expect that closing those gaps—by training people to work in safer ways—will improve workplace safety at the Lab. In a very real sense, the course is designed to give students specific, identifiable skills. We'll often ask a subject-matter expert to help us identify those skills by completing the phrase: "After successfully completing this course, you will be able to…" This gives us a sense of what problems the course is intended to solve. The things the course must teach the learner to do are the *learning objectives* of the course.

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[10] Bloom, B. S.; Engelhart, M. D.; Furst, E. J.; Hill, W. H.; Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals*. Handbook I: Cognitive domain. New York: David McKay Company.
[11] Anderson, Lorin W.; Krathwohl, David R., eds. (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives*. Allyn and Bacon. ISBN 978-0-8013-1903-7.

To create courses that jumpstart learner practice, we need to ensure that the course has learning objectives at the **Applying** level or above on Bloom's Taxonomy. One thing that distinguishes objectives at the **Remembering** or **Understanding** levels from objectives at the **Applying** level or above is that the former are described with unobservable verbs that don't require any action from the learner, while the latter are described with observable "action" verbs that describe some sort of performance.
For example, compare the following:

Awareness Objectives	Performance Objectives
After completing this course, you will: • Understand when LOTO is required • Know who is qualified to perform LOTO • Be familiar with our LOTO policies • Know the steps to performing LOTO correctly	After completing this course, you will be able to: • Perform LOTO, when required, in accordance with our LOTO policies • Assign only qualified people to perform LOTO

You can see that in the first column, all the objectives begin with verbs that are unobservable. You can't observe someone "knowing," "understanding," or "being familiar" with a concept. Further, tests to see if students have mastered these objectives generally involve questions at the **Remembering** and **Understanding** levels of Bloom's Taxonomy, which are *below* our target of **Applying**.

For example, the question, "When is LOTO required?" requires you to remember the list of conditions that make LOTO required. It is a **Remembering** question. Similarly, the question, "List the steps for performing LOTO" is also a **Remembering** question. A student may or may not be able to remember the steps, but even if she does remember them, it doesn't follow that she can perform LOTO well. To assess if she can *perform* LOTO well, we have to make *that* the objective and ask the student to actually perform LOTO, not just list the process steps. If we ask the learner to "Perform LOTO" that is *not* a **Remembering** level question—it requires more than just remembering; it requires applying knowledge to an actual task. It is an **Applying** question, which is what we want. Of course, in order to perform LOTO correctly, she has to know the steps. To help with that, we would want to develop performance support job aids that are used in the training, and later in the field. We wouldn't expect new learners to remember a seven step process reliably without a lot of practice.

The "Performance" objectives in the second column of the table, above, are good examples. They use verbs ("Perform", "Assign") which are observable and which focus on actions and decisions, not just information.

What frequently happens is that we'll engage with a subject-matter expert (SME) on a particular topic such as pressurized gas safety at the start of a project, and the conversation will go something like this:

SME: "Anyone using pressurized gas cylinders needs to know how to read the markings on a cylinder."

Unfortunately, the verb in that objective is "know." So as savvy instructional designers (IDs), we would try to refocus the objective on actions and decisions by asking the SME to articulate *why* an employee needs to "know."

ID: "So, employees need to know how to read the markings on a cylinder in order to …what? How does the

information on the cylinder get used in their jobs?"
SME: "Well, suppose I ask you to go get an oxygen cylinder at 2400 psi from storage. If you can't read the markings, how will you know which one to bring back?"
ID: "Is retrieving a cylinder from storage something our folks do?"
SME: "Yes, all the time."

By asking "why," we are able to get to an action-oriented learning objective, which in this case might be "Choose a desired cylinder from a set of cylinders based on a clear understanding of how to interpret the labels and other markings on the cylinders." The verb is now "choose," which is observable, rather than "know," which is not. Further, this drives the course design toward making sure learners can perform realistic tasks like bringing back the right cylinder from storage.

2. Create CCAFs for Each Learning Objective

Michael Allen[12] coined the acronym "CCAF" to represent the four elements of a good learning interaction: Context, Challenge, Activity, and Feedback.

- **Context**: The setting in which learners will perform a task or solve a problem.
- **Challenge**: The problem the learners must solve or the task they must perform.
- **Activity**: The set of interactions the learner will perform in the course to solve the challenge (in e-learning this usually involves clicking or dragging something, or entering answers into free-form text boxes).
- **Feedback**: The information learners receive in response to the decisions and/or actions they took.

After we establish a set of action-oriented learning objectives, you will see that each suggests how a student could demonstrate mastery of it. Take, for example, the learning objective we uncovered earlier: "Choose a desired cylinder from a set of cylinders based on a clear understanding of how to interpret the labels and other markings on the cylinders." How could a student prove that he or she can do this? The verb is "choose" so the objective implies that at some point in the course, we will have to give the learner a chance to "choose a desired cylinder from a set of cylinders…"

In the early stages of the design, we might take each learning objective and build a CCAF table to make sure we capture all four parts of an effective learning interaction:

Objective	Context	Challenge	Activity	Feedback
Choose a desired cylinder from a set of cylinders based on a clear understanding of how to interpret the labels and other markings on the cylinders	Your Activity Lead tells you that she noticed that the oxygen cylinder attached to your experiment is almost empty and she asks you to go to storage and retrieve a new one. "It has to be oxygen at 2400 psi,"	At the storage rack, you have to decide which of the 4 cylinders contains oxygen at 2400 psi.	Click the cylinder that contains oxygen at 2400 psi	How do you know?

[12] Allen, Michael W. *Michael Allen's Guide to e-Learning : building interactive, fun, and effective learning programs for any company*. Hoboken, N.J: John Wiley, 2003.

	she says. You say "OK" and head over to the storage rack.			

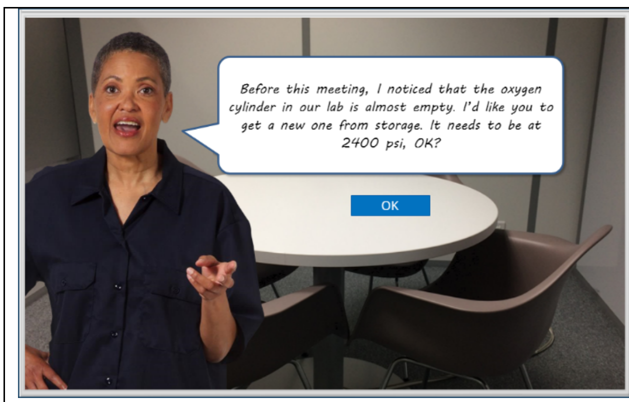
Instead of Correct/Incorrect feedback, we might decide to ask learners to justify their answers, this leads to a follow-on interaction which we also designed in a CCAF table:

Objective	Context	Challenge	Activity	Feedback
Choose a desired cylinder from a set of cylinders based on a clear understanding of how to interpret the labels and other markings on the cylinders	You say you want to bring back this [the cylinder the learner clicked] cylinder. How do you know it contains oxygen?	Identify the part of the cylinder that confirms that it contains oxygen as opposed to some other gas.	Click the part of the cylinder that tells you it contains oxygen.	Correct/Incorrect

And so on. The idea is that for every identified learning objective, we use the CCAF method to design an interaction that gives learners the opportunity to practice that objective and/or demonstrate mastery of it. Our courses are ideally a sequence of these challenges, each with a realistic job context and some feedback about the learner's performance. This design methodology helps us keep the focus on learner *performance* and not on information for its own sake.

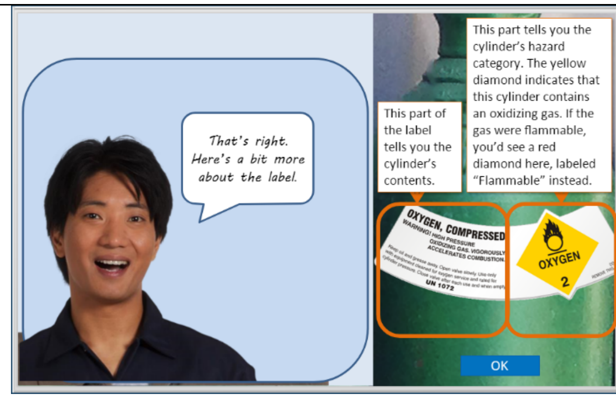
When we have the basic design of the interactions worked out in CCAF tables, we can then build these interactions in an e-learning authoring tool or create worksheets for use as table activities in a classroom.

The second "C" in CCAF stands for "Context" and if we are creating e-learning, context has a big influence not only on the design of the learning interaction, but also on the *visual* design of the interactions. Here's how the interaction we designed above might look after we build it out:



❶ Your manager Claire (in a conference room) says: "Before this meeting, I noticed that the oxygen cylinder in our lab is almost empty. I'd like you to get a new one from storage. It needs to be at 2400 psi, OK?"

❷ After you click **OK**, you end up at the storage rack with your co-worker Paul. Paul says: "Claire asked us to bring back an oxygen cylinder at 2400 psi. There are **two** oxygen cylinders here. Which one should we take back to the lab?"

	You can then click **Examine the Cylinders** to get a closer look at them.
 ❸ In the close-up view, you can use the left and right scroll arrows to see the adjacent cylinders.	 ❹ Clicking the **Right Scroll Arrow** brings the correct oxygen cylinder into view (the one on the right in the picture above). Then you click it to select it.
 ❺ Now that you've selected a cylinder, Paul quizzes you, asking: "You think we should bring back this one. How do you know it contains oxygen?" You click the yellow-and-white label as a response.	 ❻ Quan, an expert character introduced earlier in the course, confirms that the label is what tells you the cylinder's contents. So you know you clicked the right thing. Quan also takes the opportunity to tell you a little bit more about how to read the label.

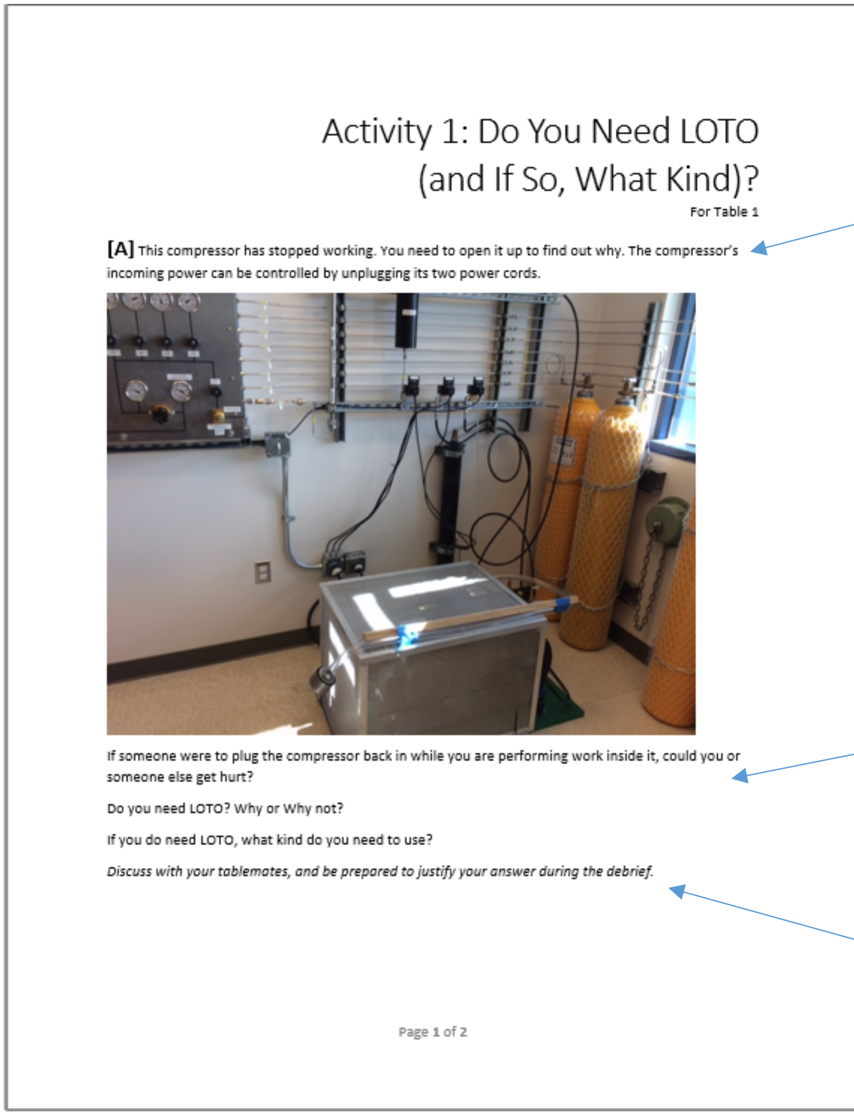
If we are designing a classroom-based course instead of an online e-learning course, the principles are the same, but the build-out format is different.

Here's a row from a CCAF table from a LOTO Authorized Persons classroom course:

Objective	Context	Challenge	Activity	Feedback
Choose the right kind of LOTO to use (or no LOTO if LOTO is unnecessary) for a variety of typical electrical tasks.	This compressor has stopped working. You need to open it up to find out why. The compressor's incoming power can be controlled by unplugging its two power cords.	If someone were to plug the compressor back in while you are performing work inside it, could you or someone else get hurt? Do you need LOTO? Why or Why not? If you do need	Discuss with your tablemates, and be prepared to justify your answers during the debrief.	Discussion during debrief: feedback from instructor and other tables/other students.

		LOTO, what kind do you need to use?		

For classroom use, we implemented this row as follows. We break the class up into 3 tables. Each table gets an “Activity Sheet” which sets the context, challenge, and activity that students are to work on for a specified time period (in this case, 10 minutes). Here’s what the Activity Sheet looks like:



Activity 1: Do You Need LOTO (and If So, What Kind)?

For Table 1

[A] This compressor has stopped working. You need to open it up to find out why. The compressor’s incoming power can be controlled by unplugging its two power cords.

If someone were to plug the compressor back in while you are performing work inside it, could you or someone else get hurt?

Do you need LOTO? Why or Why not?

If you do need LOTO, what kind do you need to use?

Discuss with your tablemates, and be prepared to justify your answer during the debrief.

Page 1 of 2

Context: This compressor has stopped working. You need to open it up to find out why. The compressor’s incoming power can be controlled by unplugging its two power cords.

Challenge: If someone were to plug the compressor back in while you are performing work inside it, could you or someone else get hurt?
Do you need LOTO? Why or Why not?
If you do need LOTO, what kind do you need to use?

Activity: *Discuss with your tablemates, and be prepared to justify your answers during the debrief.*

After the 10 minutes are up, the class facilitator brings the class back together and begins a “debrief” session in which each table reports out its results and gets feedback (the “F” in “CCAF”) from the facilitator and/or the other tables.

In either case—e-learning or classroom—we need photos and a clear understanding of the job and the job context so we can create these practice opportunities for learners.

Benefits

Principle	Benefits
Jumpstart learner practice	• Research shows practice in simulation is more effective than a lecture. • Practicing skills creates the need for learners to recall the supporting information from memory, which is crucial to helping learners encode what they learn into long-term memory • Practicing builds learner confidence • Practice improves the likelihood that learners will use their newly learned skills in the real world after they complete the training[13] • Practice makes abstract concepts concrete and helps learners better understand the situations in which they will be able to use the new skills they are learning • Practice is a key principle of andragogy (adult learning) which holds that experience should provide the basis for learning activities and that adult-learning should be problem-centered rather than content-oriented[14]
Practice skills in context	• Research shows that when the learning context matches the performance context, performance is improved • Authentic contexts help learners better understand the situations in which they will be able to use the new skills they are learning • Exact physical likeness to the learner's eventual performance context is not as important as the cognitive likeness; problem contexts only need to be "good enough" to enable authentic decision making. • Authentic contexts make clear the relevance of the learning task to the learner. This is also consistent with andragogy which holds that adults prefer to learn things that have immediate relevance to their jobs or personal lives.
Prioritize actions over memorization	• By focusing on actions instead of rote memorization of facts, we help learners understand what we're asking them to do with the information we provide.
Isolate, then integrate	• Practicing sub-skills in isolation allows learners to build up to performing complex tasks by first mastering the smaller, more manageable sub-tasks, and then integrating them together later. This approach has the benefit of managing cognitive load throughout the learning process, keeping mental capacity available for learning.

Conclusion

Berkeley Lab Training at Berkeley Lab is committed to developing training that can actually improve learner safety. While we recognize the need to convey certain information in our courses, we remain laser-focused

[13] Grossman, R., & Salas, E. (2011). The transfer of training: What really matters. International Journal of Training & Development, 15(2), 103-120.
[14] Culatta, Richard, & Kearsley, Greg (unknown date). Andragogy (Malcolm Knowles). Retrieved from https://www.instructionaldesign.org/theories/andragogy/ on 15 May 2019.

on information that informs learner decisions or actions, and we focus most of our instructional efforts on getting learners to practice making those safe decisions and taking those safe actions.

By jumpstarting learner practice this way, we begin the process of helping learners achieve fluency with safe work practices.

By insisting that learners practice skills in context, we help them see how these skills apply to their real-world work and improve the likelihood that they will apply what they learn in class to their jobs outside of class.

By prioritizing actions over memorization, we narrow our focus to the information that informs the most important safe work practices, ensuring that our limited training resources can have the largest positive impact on learner safety.

By isolating sub-skills from complex tasks before integrating them into full-task performance, we ensure that we do not overload learners with more than they can process, instead building up skills from more manageable sub-skills.

Our SMEs and other partners and collaborators are key to the success of this vision. Creating training of this depth requires the skills and knowledge of all involved. We cannot do it well without your willing support and participation.