Clark N. Quinn

Learning Science

for Instructional Designers

From Cognition to Application

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To all the researchers who advance our understanding of learning, and the designers who apply that research to create effective and engaging learning experiences.

Contents

Preface

If we're truly being professionals about designing learning, there's a clear onus to be aware of what learning science tells us. And that runs from the cognitive story at the core through to the learning prescriptions that emerge. Quite simply, we have a responsibility.

If a doctor pursues approaches unjustified by science, they're liable for malpractice. Similarly, we should be implementing scrutable practices. There are consequences for not doing so. If we use approaches that aren't justified, we can squander resources, but more importantly, we can undermine our own goals. In the worst case, lives are lost. In fact, you'll see that industries with significant potential downsides of getting it wrong practice in ways not typically seen in corporate America. Look at the military and airlines as two examples.

So, we have a responsibility to our learners, our organizations, and ourselves to understand and apply what's known, whether from a deep-seated curiosity and caring, or just because it's what's required of us.

I come from the former category. I was kind of at loose ends, degree-wise. I was tutoring (physics, calculus, chemistry) on campus for some extra income, and taking some computer science courses. I ended up doing computer support for the office that coordinated the tutoring. And a light went on: computers supporting learning! My university didn't have an appropriate degree program (back then, many didn't; I was carrying around decks of punch cards in order to run the computer programs), but it *did* have a way to design your own. So, that's what I did, and learning design and technology has been my career ever since.

I've programmed educational computer games; gone back for a PhD in what was, effectively, applied cognitive science; and gone the academic route: a post-doctoral and then a faculty position. For complicated reasons, I also joined some government-sponsored initiatives in online learning before joining a startup in educational technology. When that went four paws to the moon in the economic chaos that characterized the collapse of the internet bubble, I ended up as a consultant (which went from being a euphemism for unemployed to a way of life).

However, my career has always been about exploring ways to use technology that allow us to pursue our goals more effectively and efficiently.

Along the way, I've maintained a passionate interest at the intersection of four related fields. I've looked at learning—behavioral, cognitive, post-cognitive, social, educational, even *machine* learning—to see what's known. Similarly, I've followed what's known about engagement, including motivation, anxiety, curiosity, drama, and humor, to understand how we create experiences that are meaningful, even transformative. I've also followed technology trends from before personal computers, including artificial intelligence, mobile, content systems, constructed realities (augmented and virtual), and more, to find out what new capabilities we might use. Finally, I've looked at design, including interaction, industrial, graphic, software engineering, and of course instructional approaches, to ensure that we're applying this knowledge in the most useful ways.

That's my mission: Discover how to create experiences that tap into our hearts and apply our minds to achieve useful ends. It's all about strategic learning experience design (LXD). (And through technology, since I'm admittedly a sucker for the latest toy.) Which means I have looked at practical ways to integrate this suite of knowledge. Here, I'm focusing on learning, and its application to instruction.

And, as you'll see, our brains consolidate information. We don't remember many exact details; instead, we remember a synthesis. And that's what I'm doing here. This is not a detailed academic treatise, but rather an attempt to digest and communicate a practical interpretation of what's known about cognition and learning to provide a basis for better design.

I hope you find it comprehensible and useful.

Acknowledgments

There are so many people I owe gratitude to, and I've tried to catalog them in previous books. A few who continue to support me include the following.

Jim "Sky" Schuyler has been a mentor, colleague, and friend since out of college and continuing on. A great role model.

Marcia Conner has been a mentor at stages in my career, providing opportunities and helping me learn important lessons.

My Internet Time Alliance colleagues, instigated by the late, great Jay Cross—Jane Hart, Harold Jarche, and Charles Jennings—all have served to improve my understanding of learning and life.

My IBSTPI colleagues, including Mark Lee, Kathy Jackson, Davida Sharpe, Fernando Senior, Saul Carliner, Florence Martin, and Stella Porto, have been sources of inspiration and learning.

Thanks also to all my colleagues in many different forums; in particular (and in no particular order), Will Thalheimer, Karl Kapp, Patti Shank, Julie Dirksen, Mirjam Neelen, Donald Clark, Jane Bozarth, Jen Murphy, Chad Udell, Connie Malamed, Matthew Richter, Guy Wallace, and the other mythbusters and science interpreters have all helped shape my rigor and understanding. Apologies if I haven't mentioned you! And I'm grateful to so many more colleagues who inspire me and support us all in doing better.

I'm grateful to all the organizations that have given me platforms to share my thinking on how to improve the field, through workshops, keynotes, talks, articles, books, and courses. Thanks to societies, publishers, private organizations, individuals, and more.

Also, thanks to the organizations that have brought me in to work with them. It's a deep pleasure to be able to get hands-on with real problems and try to "Quinnovate" some new ideas. I've learned so much from these opportunities with public and private companies, not-for-profits, governmental bodies, educational institutions, and more.

I'm also grateful to Justin Brusino, Alexandria Clapp, Jack Harlow, Melissa Jones, Caroline Coppel, Hannah Sternberg, Shirley Raybuck, Rose Richey, Stephanie Shaw, and the rest of the ATD team who've pushed and supported me through this experience. This book exists because of Justin and Alexandria is immeasurably better because of Alexandria, Jack, Hannah, and Caroline, and looks great thanks to Melissa, Shirley, Rose, and Stephanie.

My family—Erin (who served as a reviewer of an early draft), Declan, and most of all, LeAnn—have been stalwart supporters. With love and gratitude.

CHAPTER 1

Introduction to Learning Science

- What is learning science?
- Why we need learning science
- How learning science is conducted
- How to find learning science resources

> **plunger** (plŭn′jər)
> The plunger in the pump was broken. A *plunger* is a:
> (a) dolphin
> (b) pump part
> (c) brown car
> —A found example of online learning

What possible learning purpose does this example serve? The question comes right after the content. It asks a question where the answer is implied by the immediately preceding material, and the alternatives are nonsensical or silly.

This example is emblematic of why we need learning science. Because when we design learning experiences, we want to achieve an outcome. And, if we don't do it according to learning science, we could waste our stakeholders' resources and our learners' time.

To address the need in this book, we'll go through basic cognitive architecture, and then the learning phenomena (cognitive artifacts like mental models) of reasoning that arise from this architecture. We'll look beyond cognitive to emotional aspects, and we'll point out the implications for learning experiences and the design of specific elements.

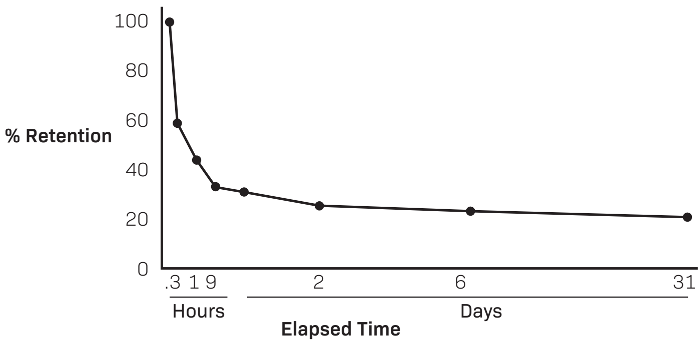
First, however, we should establish more about the science we're investigating.

What *Is* This Learning Science?

Learning science is, not surprisingly, the scientific study of learning. It means looking at how learning works, and also what facilitates and hinders learning. It provides a strong basis for designing instruction. It is relatively new, however.

Our brains are the core organs of learning. We perceive the world, act, observe the outcomes, and reflect. Consequently, studying learning comes from studying the mind. The ancient Greeks philosophized about how our brains work, but scientific exploration of learning really only began with Hermann Ebbinghaus's studies of memory in the 1800s (Figure 1-1).

Figure 1-1. Ebbinghaus's Memory Study



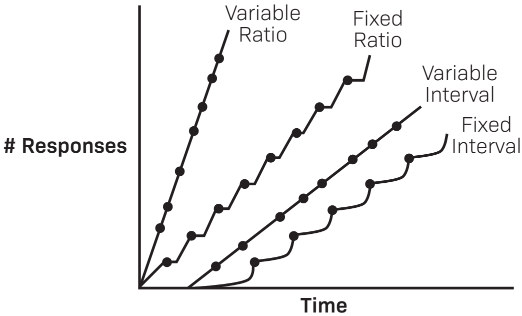
The field of psychology has subsequently gone through several movements, including behaviorist, cognitive, and constructivist. Each of these added insights have furthered our understanding.

The behaviorist school started out by saying that we can't talk about what's going on inside the brain; we only can connect inputs with outputs. This was the era of Pavlovian conditioning and stimulus-response approaches. Robust findings include the value of different reinforcement schedules (think gambling; Figure 1-2) and the Yerkes-Dodson performance-arousal curve.

The cognitive revolution said that we can hypothesize what brain structures must exist. Research showed various facets of our information processing that have stood the test of time. There was a vision that we were formal, logical reasoners.

Revelations that we're not the formal-thinking beings we thought prompted the move to a more *situated*, or constructivist, view of cognition. Here, we realize that our thoughts are an interaction between context and previous experience. We may use concepts differently depending on context, and certain types of reasoning are problematic.

Figure 1-2. Reinforcement Schedules



Importantly, psychology isn't the only field that talks about how our minds work. Insight still comes from fields such as philosophy, neuroscience, linguistics, anthropology, and sociology. The field of cognitive science was created to be an umbrella under which these differing elements could be integrated. And it's provided a solid foundation for developments including communication and collaboration practices, interface design, and artificial intelligence.

Learning science is similarly interdisciplinary. Research insights have come from psychological investigations, educational studies, ethnographic approaches, and sociological work. (A side effect is that results from one discipline may not take into account results from another, related discipline.) A growing awareness of this relatedness led to the establishment of the discipline in the 1990s.

Learning science is also global. I was a graduate student in the United States during the establishment of the discipline, and then a post-doctoral fellow. There is so much research done in the US, it was easy for me be focused nationally instead of internationally.

Later, I had the good fortune to take a faculty position in Australia, and quickly (and shamefacedly) learned my awareness of research was blinkered. I was also able to visit global conferences and get exposed not only to the field's interdisciplinary nature, but also to its global cohort of researchers. And it's important to realize, and recognize, that the results and implications properly span cultures and nationalities.

Why Should *We* Care?

Another plausible question is *why* learning science? Why should we understand the underlying cognitive mechanisms, the artifacts and limitations of our mental architecture, and the associated elements? Can't we just follow the resulting precepts of instructional design? I'll suggest that the answer is a resounding "no."

My short answer is that it's a professional imperative. Instructional design is applied learning science. How can we claim to be scrutable in our approaches if we don't track the underlying research, and can't articulate how our designs reflect what is known? Just as you expect your doctor and financial adviser to be applying the latest outcomes, so too should you feel such an obligation when designing learning experiences. We don't want to be guilty of design malpractice, after all.

The longer answer starts with the realization that instructional design is a dynamic field. Even David Merrill, one of the founders of and forces in instructional design (and a truly nice person to boot), has had phases of change. His Component Display Theory, for instance, progressed to ID2, and now he's on about a "pebble in a pond." New understandings in learning science drive the need to revise our approaches.

The foundations we build our design processes on have shifted. Instructional design emerged as an artifact of World War II, when behaviorism was in force. As we've gone through the cognitive era and into a post-cognitive constructivist awareness, our design bases similarly adapted. Each of those transitions has had implications for what we think learning is, and consequently what makes sense as pedagogy.

Recent understandings continue to drive our approaches. To be able to react to new approaches means grasping some fundamental underpinnings. Separating them from other explanations is a critical component of being a successful practitioner. (I once was presented with a "hydraulic" model of learning, an engineering metaphor misapplied to understanding our thinking!)

This implies a second reason to understand the basics: Folks will continue to propose new approaches. They will come to these approaches sometimes from pure conviction, rightly or wrongly, but also for commercial reasons. Practitioners need to be careful about evaluating new claims. With an understanding of the basic mechanisms, you're better prepared to avoid the learning myths that plague our field (as I documented in my last tome, *Millennials, Goldfish & Other Training Misconceptions*).

Also, instructional design has great recommendations, such as we see in the movement to evidence-based methods as discussed in recent books by Ruth Clark and by Mirjam Neelen and Paul Kirschner. Thus, a third reason is that there are still gaps that prescriptions won't fill. Making good choices in lieu of guidance depends on understanding the mechanisms as suggested by theories.

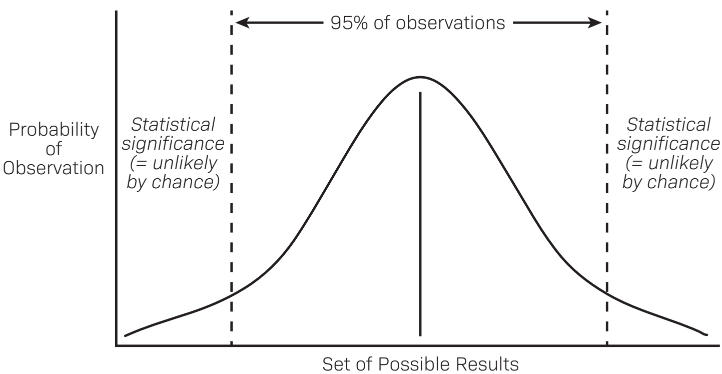
How Does One "Learning Science"?

Learning science is the result of the usual processes of science. While there are many different methods, the basis we should be using is the result of experimentally tested and statistically validated approaches.

A major distinction is between quantitative and qualitative studies. In quantitative studies, you have clear metrics that are objectively obtained, such as scores on tests or observationally clear performance while completing tasks. Here we typically have some subjects working in one way (such as under the experimental treatment), and a control group in another, typically pre-existing, way, and we then look at the outcomes.

Statistics are used to determine with some degree of certainty whether the outcome is due to chance (Figure 1-3). It is a probabilistic game, because even significant tests have a chance of being false 5 percent of the time. This is one of the reasons it is preferable if the results are replicated. Reputable reports, such as those in a peer-reviewed journal or book chapter, will detail the study sufficiently so that someone can conduct the same study. And this happens.

Figure 1-3. Statistical Significance



Note that despite their empirical nature, experiments tend to be driven by theory. While there are some purely experimental studies ("What will we find?"), most times someone creates a hypothesis, and then tests it. For instance, someone may say, "Hmm, one prediction of cognitive load theory might be that we need to integrate labels into diagrams to keep people from generating more mental overhead by looking back and forth between them, trying to integrate the element and its meaning." They run a test, and find out if it's true (spoiler: it is).

Qualitative studies similarly use the scientific method, but they take data that's more complex than just numbers (verbal protocols, interviews) and code it, and then look for patterns. Typically, you need some controls on the interpretation to support the resulting analysis, such as someone independently coding a subset of the data and looking for the agreement. For my PhD thesis, for instance, I coded transcripts of subjects' verbal efforts in problem solving. As a control, I also hired a student to code a subset of the data using my rubric, and checked to see that the coding was reliably consistent. Finding (and reporting) that the degree of agreement was sufficiently high meant that we could then report that the data was reliably coded.

Importantly, your data should get reported in a journal. What this means is that you write it up in unambiguous language and peers review it, and it must pass scrutiny. Along with the results, you situate your work in others', via a literature review, and you make clear what the unique contribution is. The peer scrutiny can be a problem, particularly if the work is upending established protocol. There's a whole field of science *about* science, and concepts like Thomas Kuhn's paradigm shift are used to characterize the bigger changes. Yet overall the process works.

Be aware that the language used for journals is an obscure dialect known as academese. This is typically based on English, but uses an esoteric and almost deliberately impenetrable vocabulary. It takes training to be able to comprehend it. Learning to read academese is a valuable skill, but probably not for most folks.

At its core, however, the systematic process of experimentation and theory advancement, as well as theory revision and replacement, is all part of science. And its results are the best basis upon which to determine our approaches.

On the Lookout for Learning Science

As suggested, the best way to track science is to read journals. And, again, not everyone should be expected to read them. The nuances of appropriate methodologies are subtle, and not necessarily of use to all. What to do instead?

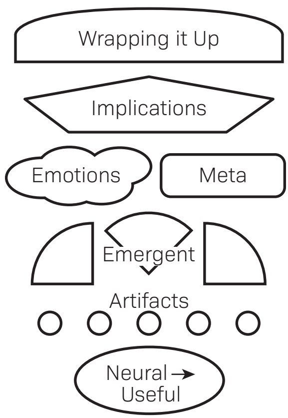
Fortunately, there is a cohort of folks who are reliable translators. In addition to the scientists—those who can reliably communicate to laypeople, and that's not all of them—are folks steeped in the traditions (typically with PhDs from experimental programs) but who work in the real world. A number of them continue to serve as valuable proponents for applications of the science.

These translators write blog posts, articles, chapters, and books. They present via webinars, conferences, and keynotes. You should know them, listen to them, and, of course, hire them. They can do workshops to educate your team, consult to improve your processes, and help you plan to better align. They're the source of the best principles to apply to your practices. I maintain a list of the best translators at quinnovation.com/translators.html. And you should know the places where translation writings aggregate. Not every place is rigorous about the quality of its materials.

The Rest of the Book

With that all said, what am I going to cover? I think it's important to work our way up from the fundamentals of the brain to what that means for learning. This means a steady progression through several areas (Figure 1-4).

Figure 1-4. Book Structure



First, we'll look at our cognitive architecture using a "stores and processes" model. Here we'll learn the basic information-processing cycle, from sensed signals to long-term memory.

The artifacts for learning that emerge from this architecture are next. Tied in to attention and working memory limitations is cognitive load. Similarly, specific elements around models have implications from refining retrieval to developing content.

We'll then review the phenomena that are outcomes of this architecture. We'll look at some more recent frameworks that document some characteristics of our thinking that are not logical, and what that means. This includes looking at processing media.

From there we'll go beyond the cognitive to the emotional—or, rather, affective and conative (who we are and our intent to learn). We'll explore what's known about experience, motivation, and more.

We'll also examine learning to learn. This important area is often neglected, yet it can have an impact on success. This includes a culture of learning.

Then we'll delve into the implications of all this science on the elements of learning design. We'll explore introductions and closings, concept models, examples, and, of course, practice.

And we'll look at the elements in another way, as sets of prescriptions for design. This includes two frameworks and a detailed example.

Overall, our journey is:

- Chapter 2: Our brains, from the neural level to the level of language
- Chapter 3: Learning artifacts that arise from our architecture
- Chapter 4: Some new perspectives with implications for learning
- Chapter 5: The emotional side of learning
- Chapter 6: Learning to learn
- Chapter 7: Learning experience design implications
- Chapter 8: How it all fits together

That's it—buckle up; it's going to be a wild ride!

Activities

How do you get the most out of this book?

- Reframe the content, whether mentally, into different terms, or physically, in terms of rewriting core ideas, mind-mapping the content, or sketch-noting it.

- Reflect on how the content explains things you've experienced in the past, including good and bad learning.
- As you work through the content, ask: What does this imply that I should do (differently)?
- Make it a habit to track learning science translations and translators.

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About the Author

Clark Quinn assists Fortune 500, education, government, and not-for-profit organizations in integrating learning science and engagement into their design processes. He has a track record of innovation, and has consistently led development of advanced uses of technology, including mobile, performance support, and intelligently adaptive learning systems, as well as award-winning online content, educational computer games, and websites. Previously, Clark headed research and development efforts for Knowledge Universe Interactive Studio, and held management positions at Open Net and Access CMC, two Australian initiatives in internet-based multimedia and education.

Clark is a recognized scholar in the field of learning technology, having held positions at the University of New South Wales, the University of Pittsburgh's Learning Research and Development Center, and San Diego State University's Center for Research in Mathematics and Science Education. He earned a PhD in cognitive psychology from the University of California, San Diego, after working for DesignWare, an early educational-software company.

Clark keynotes both nationally and internationally and is the author of numerous articles and chapters, as well as the books *Engaging Learning: Designing e-Learning Simulation Games*, *Designing mLearning: Tapping Into the Mobile Revolution for Organizational Performance*, *The Mobile Academy: mLearning for Higher Education*, *Revolutionize Learning & Development: Performance & Innovation Strategy for the Information Age*, and *Millennials, Goldfish & Other Training Misconceptions: Debunking Learning Myths and Superstitions*. In 2012 he was awarded the eLearning Guild's first Guild Master designation. He blogs at Learnlets.com, tweets as @quinnovator, and serves as executive director of Quinnovation.

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