The LeanMan

Lean Factory Simulation Kits

LEAN PRINCIPLES TRAINING OVERVIEW

With The LeanMan Lean Principles Factory Simulation Kits© you can create adult learner oriented lean manufacturing instructional materials that come alive—that enable learners to do far more than just read or listen. They will become part of the demonstrations, try out lean procedures, experience the hands-on simulations, get feedback and help, be able to question the lean idea or concept and get meaningful answers, and more.

What you bring to the experience as the Facilitator is of the utmost importance. You know your Lean Principles subject matter, of course, and you should have a clear sense of exactly what you want to teach. It will help if you have some basic familiarity with the shop operation and your student's work environment. Most important, you have to understand how adult learners learn.

The Five Principles of Lean*

1. Specify **Value** of the Product
2. Identify the **Value Stream** for Each Product
3. Enable the Products to **Flow** Without Interruptions
4. Allow the Customer to **Pull** Value From the Stream
5. Continuously Improve … Pursue **Perfection**

* from Lean Thinking by James Womack

Adult learning isn't a simple act. It involves a complex, interrelated series of cognitive processes, including attention, perception, and memory. Based on cognitive psychology—the science of how people process information—the principles of instructional design can help you create and present Lean Mfg training materials that are consistent with the way people learn. The LeanMan Lean Principles Factory Simulation Kits will provide you with an interactive hands-on tool to help introduce you and your team to these learning principles, and suggest (with facilitator talking points and lean flow examples) how you can combine effective instructional design with the power of simulation to create Lean Principles teaching and training materials that work, on the job and in the classroom.

The references listed will point you to further readings and resources where you can learn more about cognitive processes, instructional design, and effective learning experiences.

INSTRUCTIONAL METHODS

Suppose you were to take a course in transmission repair. Would you learn better from a computer-based slide presentation of the material? or from a "traditional" classroom lecture course? or by a combination of methods that includes the tearing down and rebuilding of a transmission with your own hands? Researchers have conducted hundreds of studies comparing the teaching and learning effectiveness of various media, only to conclude that it depends. And it doesn't depend on the medium of instruction. Most of us have experienced ineffective instruction in various media, including the classroom and hands-on training. That's because what makes good instruction isn't the medium; it's the instructional methods that guide the way the medium is used.

Methods are the instructional techniques that facilitate learning. Media are the means of implementing those methods (as well as conveying the material to be learned). For example, methods include demonstrations, animations, examples, practice, and feedback. Media include overhead slides, computers, video, workbooks, and instructors among others.

Any medium can be rendered ineffective by inappropriate methods. Take, for example, a lengthy classroom lecture where students are relentlessly bombarded with information but given no opportunity to work with it, or a learning program that allows for no interactions on the part of the student. Both overload learners with too much content while providing inadequate opportunities to build skills or practice the content being presented.

COGNITIVE LEARNING PROCESSES

Dr. Ruth Clark’s work in the science of adult learning concluded that instruction can be designed based on four different assumptions of learning. She calls these four architectures: receptive, directive, exploratory, and guided discovery.

In a **RECEPTIVE** design, the instruction provides new information that the learner absorbs as they receive it. This architecture provides relatively little in the way of learner interaction. Briefings and lectures are typical examples of the receptive architecture. The goal is to provide an overview of the subject and generate enthusiasm for it.

In a **DIRECTIVE** design short lessons are used that include rules or definitions, examples, and practice exercises. Lessons are generally sequenced starting with easier or prerequisite skills, and build gradually to more complex skills. Frequent questions with feedback are provided to build patterns of correct associations. This architecture is based on behavioral principles of psychology and served as the predominant architecture of early instructional training. Learners are guided step by step to take the correct path. If they make a mistake, corrective feedback is given—followed by an opportunity to try again.

The **EXPLORATORY** learner is free to access diverse repositories of information that can include demonstrations, examples, and practice exercises. The role of instruction is to provide a rich layered resource of information so learners can acquire the knowledge they need by self-navigation. The burden of motivation and dedication to learn is placed on the learner.

The **GUIDED DISCOVERY** is the most effective means of teaching Lean Principles because it immerses learners into typical production problem situations and provides support for their solutions. This instructional design is somewhat learner controlled and uses greater amounts of simulation, but the key is that it is directed toward how instructional methods interact with learner mental events and cognitive memory.

One type of guided discovery instruction is called the cognitive apprenticeship. Its main features include experiential learning in which learners are immersed in job-like problems and—with various support options including facilitators, reference, and best practice models—are encouraged to solve the problems. The LeanMan Lean Principles training simulation exercises encourage the use of experiment with the Learning to See the Waste 10-Second Test, the 15-Minute Observation and the Kaizen event. Learners are provided real flow patterns to study, they are situated at familiar work settings, they are given access to typical work tools and forms just as they would use in the shop, and they are given lean principles information and facilitator assistance. In this way the skills and knowledge gained in the simulation become part of their associative environment when they return to their normal work place.

LEAN PRINCIPLES LEARNING PROCESS

Each of the four architectures is powerful for specific performance outcomes and learning audiences. In brief, there is one major Lean Principles training outcome you desire: to perform. Perform outcomes imply the acquisition of new knowledge and skills. Perform outcomes in turn can be divided into two major categories: procedural and principle-based. Procedural outcomes are those that support learning of step-by-step tasks that are completed in the same way each time.

Principle outcomes support tasks that require judgment in adapting guidelines to unique situations each time. For example, assembling a product in the shop or loading fixtures into a test chamber are procedural tasks; while inspecting a painted finish or balancing workload within a work cell are more principled in nature. The Lean Principles training goal is to create Lean Thinkers and to enable workers to make the daily good decisions necessary to maintain the principles of lean flow. Doing so requires learners to acquire both procedural and principle based knowledge. The table below summarizes the benefits of the guided discovery method.

Guided discovery	Problem-based Situates learning in job-like environment Uses simulation to compress experience Errors are encouraged Support is provided through coaching and expert models	To build expert-like problem solving knowledge and skills To accelerate expertise in principle-based domains	Acquiring skills in principle-based domains where daily decisions require analysis of situations and application of learned principles. Acquiring skills in procedural-based domains where lean principles of value, value stream, flow, pull, and perfection are applied in the daily hands-on activities of work.

THE HUMAN COGNITIVE PROCESSES

Information enters the brain through the senses—primarily, in most educational settings, through the eyes and ears. Where attention is directed, it is the information that's perceived that moves into the working memory of the brain. To be learned, the information must be moved from working memory into long-term memory. This process is probably familiar to you. For example, when you hear someone's name for the first time, you probably remember the name as long as you're talking to the person. But unless you make a conscious effort to really learn the name—for example, by associating the person and the name with a particular image—you're likely to forget it later on.

Working memory is the main work area for thought, the conscious center of the brain. But its storage capacity is limited. Think of working memory as a small chalkboard. You start writing information on it, and it quickly fills up. Soon, you have to erase the board in order to put more information on it. In order to save the information you're erasing, you need to write it somewhere else—say, on a piece of paper, which is long-term memory. But you're working against time, so not everything on the chalkboard will be captured on the paper—some of it will be erased before you have time to copy it down.

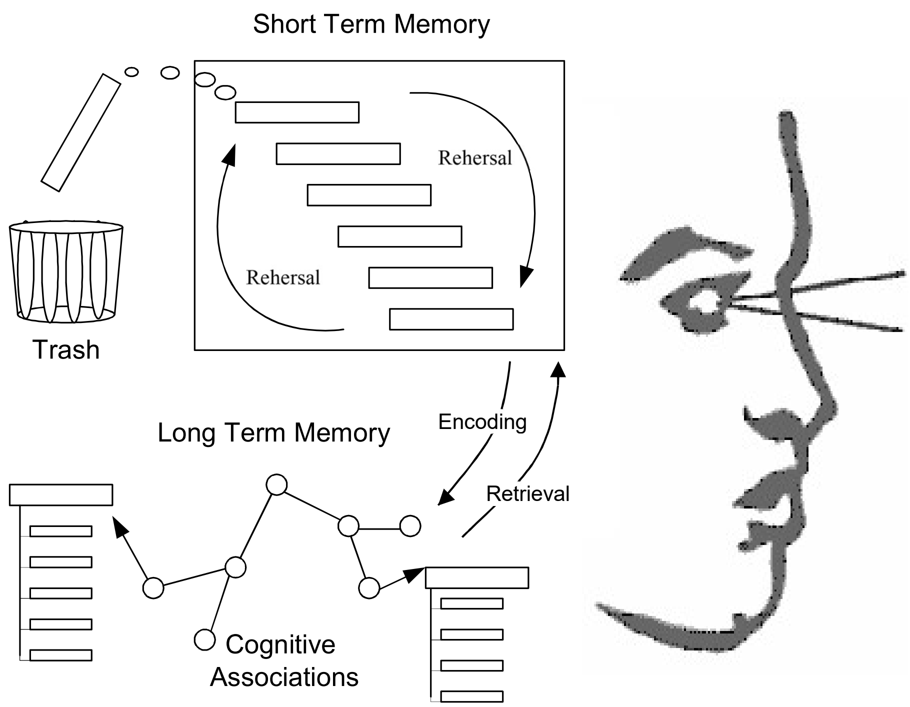
> ***Because of its limited capacity, working memory is the bottleneck in human information processing.***

Most importantly, the limited capacity of working memory defines one key goal of effective teaching and training: to move knowledge and skills through working memory into permanent storage in long-term memory.

While in working memory, information must be used or practiced in some way or it will be lost. In cognitive psychology, the technical term used for this process is rehearsal. Rehearsal is what you do when you form a visual image or reorganize information in your mind so that you'll remember it later. When rehearsal is effective, it succeeds in capturing, or encoding, information in long-term memory. Unlike working memory, long-term memory has a large capacity and long duration. Once information is stored there, it will probably always be there. It becomes knowledge.

But storage in long-term memory isn't enough. When knowledge is needed, it must be retrieved from long-term memory and brought back into working memory for processing. So enabling people to retrieve information from long-term memory when it's needed is the final goal of teaching and training. This is called positive transfer.

The following illustration summarizes the flow of information from the senses through working memory into long-term memory and back into working memory through the processes of attention, encoding, rehearsal, and retrieval.



The flow of information

COGNITIVE PROCESSES AND INSTRUCTION

When teaching or training fails to take these processes into account, learning is disrupted. The amount of information people can process is essential to effective teaching or training. Indeed, bombarding learners with too much information at once, called cognitive overload, is one of the chief obstacles to learning. Creating instructional materials that overwhelm the learner's processing capacity will easily sabotage the training effort.

Imagine studying a chessboard where 24 pieces are arranged in a game in progress. Could you replicate the arrangement of the pieces after looking at the board for 10 seconds? How many times would you need to look at it, for a few seconds each time, before you could reproduce it from memory? A researcher named Herbert Simon asked groups of chess masters and chess novices to perform this task. Not surprisingly, the chess masters needed fewer exposures to the board—about four, on average—to reproduce the arrangement of pieces. The novices, on the other hand, needed several more exposures—as many as ten. What accounted for such differences between the abilities of the experts and the novices? Did the experts have better memory powers, or did their superior performance simply reflect their greater experience in the game of chess?

To distinguish between these alternatives, Simon repeated the experiment, but with the pieces placed randomly on the board rather than arranged in the form of a game in progress.

Had the masters indeed enjoyed superior powers of memory, their ability to reconstruct the board would have surpassed that of the novices in both phases of the experiment. Interestingly, however, the random arrangement of the pieces in the second phase significantly disrupted the masters in their attempts to reconstruct what they had seen, while the novices, for whom the arrangement of pieces had little or no meaning, were better off.

When challenged to "learn" the chessboards they were shown in Simon's experiment, the masters engaged in what's called a top-down analysis of each one: they looked for meaningful patterns in the arrangement of the pieces, to match the many such patterns they had stored in long-term memory. But when presented with meaningless information, in the form of randomly arranged pieces, their learning process was radically disrupted.

What does this tell us about working memory?

> ***In a widely accepted formula for the capacity of working memory, researcher George Miller wrote that it can hold "seven plus or minus two chunks" of information.***

But a chunk is a relative concept. In the first phase of Simon's chessboard experiment, the novices looking at the board saw 24 separate pieces of information—that is, 24 chunks. The masters saw patterns in the arrangement of the pieces, which enabled them to process what they saw in larger, but fewer, chunks. Clearly, the more expertise one has, the larger the chunks of information one can manage in working memory.

In some ways, this can work against the Lean Learner. Consider an experienced shop worker who has many years of experience in the old traditional batch process ways and in fact is considered to be quite the expert. When placed into a Lean Principles training exercise, the “expert” really does "think differently" from the way the novices think. They group chunks of the training information differently – and sometimes wrongly – trying to chunk the new information with cognitive associations. That's why experts in the traditional Batch ‘n Queue production methods sometimes become frustrated and tend to reject the Lean Principles. The new concepts just don't feel right – they go against historical learned reason. Because they've been immersed in their area of expertise for years, they suddenly feel like the chess experts faced with random board patterns. Nothing makes sense. That is why the presentation of Lean Principles information must be made in small chunks that are simple for both expert and novices to grasp, and given time to digest the small chunks. Training developed by inexperienced trainers often produces cognitive overload in learners because the experts have failed to put themselves in the psychological shoes of the trainee.

To avoid cognitive overload, keep your training sessions simple and consistent.

Directing the Learner's Attention

Attention is the psychological mechanism learners use to select from the environment the elements they'll put into working memory. People aren't very good at paying attention to more than one thing at a time. Imagine listening to two different speeches playing at equal volume in your right and left ears. Your chances of following, much less remembering, both messages would be slim indeed. At best, you might be able to focus your attention on one of the messages, simply ignoring the other.

> ***To avoid dividing the learner's attention, use various media elements such as text, graphics, and sound to present reinforcing rather than disparate messages.***

You can actually help focus the learner's attention through a technique called instructional cueing—directing attention to the information that's most important or immediately relevant. Remember, simplicity and focus is of primary importance. Don't let the power of multimedia tempt you into creating overly elaborate presentations or they may steal focus from the very thing they're meant to highlight.

Practice, Practice, Practice

Because the limited capacity of working memory is rapidly overwhelmed when lots of new information is presented, it's crucial to provide frequent opportunities to use or practice the information in working memory.

> ***Clear working memory by encouraging frequent rehearsal, which moves information into long-term memory.***

It's important not only that learners have a lot of practice, but that the practice be provided frequently. A research study compared the effects of the same amount of practice on two groups. One group did all their practice in a single session; the other group practiced in several shorter sessions, spread out over time. The second group showed much better long-term retention of the information they had learned.

As a rule of thumb, it's important to provide practice opportunities after the presentation of each new idea or chunk of information. Because any given idea or chunk of information may require differing simulation or experimentation, it wouldn't make sense to say that you should provide an exercise after "x" number of ideas. Instead, consider the size of each new idea or chunk of information being presented. And take your audience into account. Like the chess masters in Herbert Simon's experiment, more experienced lean learners can handle more information between practice sessions because they can store larger chunks of information in working memory.

EFFECTIVE ENCODING TECHNIQUES

Practice has two complementary goals: to clear working memory and to move information into long-term memory. In cognitive psychology, the latter process is called encoding the information, and techniques that promote effective encoding are important to Lean Principles instructional design.

If you were to briefly study this list of words—spirit, rabbit, integrity, chair, focus, style, wing—which ones do you think you'd be more likely to remember several days later? Research shows that the words with concrete meanings, such as rabbit, are more memorable than abstract words like spirit. Why? One theory suggests that when you encounter a word that's concrete in meaning, your mind processes it in two different ways: phonetically (the sound of the word) and visually (the picture that forms in your mind's eye). Through this process of dual encoding, a concrete word like rabbit is lodged in your memory as two distinct, reinforcing pieces of information.

Dual encoding is at the heart of effectively teaching Lean Principles

Encourage dual encoding through the use of concrete words and different modes—for example, text, graphics, and sound—to reinforce a message.

With its rich mix of elements, simulation training is admirably suited to reinforcing information through two (or more) expressions or representations, from text to pictures to sounds. It's up to you to make the ideas and information presented as concrete as possible, and to make the various expressions of an idea congruent with each other. Remember: you always want to focus, rather than splinter, the learner's attention.

How learners get to work with information is extremely important, too. In general, information in working memory can be rehearsed or practiced in two ways. Simple repetition can be used to keep information alive in working memory. For example, you may repeat a phone number over and over to yourself while walking to the telephone. But after you dial the number, it usually slips from your memory within moments. That's because such simple rehearsal, known as rote repetition, isn't very effective at moving information from working memory to long-term memory. Questions that encourage this kind of rehearsal aren't effective instructional methods.

> ***The second type of practice, called elaborative rehearsal, is much more effective at encoding information in long-term memory.***

Elaborative rehearsal enables the learner to really interact with the information in working memory—and thereby to master the information.

To promote elaborative rehearsal, you must design simulation exercises that encourage the learner to apply knowledge in an appropriate context. In job training, for example, you might design interactions that are directly related to a job task at hand.

Avoid rote repetition in your interactions. Instead, design interactions that match job activities and skills. Such interactions serve as especially effective rehearsal opportunities because they mimic the contexts in which the learner will be called upon to use knowledge on the job.

Indeed, in job training, the more faithfully the practice opportunity mimics real-life applications of knowledge or skills, the more effective it tends to be.

> ***The phenomenon promoted by such rehearsal, called encoding specificity, is the basis for designing effective Lean Principles instruction.***

For procedural skills, The LeanMan Lean Factory Simulation exercises encourage encoding specificity through the use of high-fidelity simulation practice. Simulations attempt to replicate the actual job environment as closely as possible.

ENCODING INTO LONG-TERM MEMORY

Since the learner is solving job-realistic problems, the guided discovery provides an excellent encoding environment. The LeanMan Lean Factory exploratory environment will support encoding to the extent that good elaborative practices are included and that learners take advantage of them. Merely performing the simulation assembly operations without enforcing the lean theory will not produce good results. The goal is not to see how fast the cars can be produced, but instead to practice each of the elements of lean flow and to develop a sense of the tools of lean that can be taken back to the shop and put into practice in the real world.

> ***For optimal learning results, the facilitator should fully explain, and practice, each of the tools of lean such as The 10-Second Test, the 15-Minute Observation, the Kaizen Event Profile and the Target Progress Report (provided as part of The LeanMan Deluxe PLUS VSM kit).***

In summary, the best encoding opportunities are provided in the hands-on factory simulation exercises when coupled with the real shop data gathering and analysis tools, and practiced live in each simulation exercise (and live in the real shop if possible) so each learner has the opportunity to question the validity of the tool; to use the tool to gather and analyze real events as they occur in the exercise; and to relate how the tool might work back in the shop.

ENCOURAGING EFFECTIVE RETRIEVAL FROM LONG-TERM MEMORY

The final and most important step in learning—and the key measure of success of teaching or training—is the retrieval of what has been learned from long-term memory when it's needed. Whatever medium is used, training too often produces learners who can't retrieve the knowledge they've been taught—the knowledge they need—when they need it. This is called transfer failure.

What causes transfer failure? The way people learn things governs the way they remember them. Imagine reciting the days of the week. Easy, right? Now imagine reciting them in alphabetical order. That's a much more difficult task, because we ordinarily learn the days in chronological, not alphabetical, order: so that's how they're stored in our long-term memory.

> ***According to a researcher named E. Tulving, information can be recalled only if ways of remembering the information—called retrieval cues—are provided along with the information at the time of learning.***

Because you learned the days of the week chronologically, you lack the appropriate retrieval cues to recall them alphabetically. You have the knowledge but lack the ability to use it. The cognitive associative cues used in memory that are attached to each bit of new long term information are also the cues used to retrieve the information.

When creating Lean Principles instructional materials, then, you have to design in the retrieval cues that will facilitate recall, or retrieval, of the content of what you want to teach. It's also extremely important to build retrieval cues into rehearsal exercises. In training courses, the secret to helping the learner remember later on is to build retrieval cues from the job environment into the training. For some skills, such as frequently used procedures, it's important to create rehearsal contexts and interactions that are as close as possible to what learners will actually see on the job—like in The LeanMan Lean Factory Simulation Training exercises as discussed above.

THE PROMISE OF LEAN FACTORY SIMULATION

One type of guided discovery called the cognitive apprenticeship is the basis for the Lean Factory Simulation exercises. Consider, for example, principle-based tasks—such as work order disposition when late material finally arrives or scrap replacement—which require performers to exercise judgment and flexibility on the job: there's no one correct approach to such tasks, as there is with procedures. To be effective, performers must adjust their approach depending on the context, the issues at hand, the customer, their prior interactions with the customer, and other factors. They must exercise judgment at every turn. For them, each new unplanned event is a problem-solving situation.

Teaching problem-solving has always been more challenging than teaching procedural skills.

> ***Of the four architectures, the guided discovery approach is specifically designed to support this type of learning using cognitive apprenticeship.***

A cognitive apprenticeship is designed to build expertise. Chess masters such as the ones who participated in the Simon experiment described earlier have more than 50,000 chess situations stored in their long-term memory. It's estimated that it takes about 10 years of sustained practice to achieve such a store of knowledge. In fact, experts in all fields rely on patterns accumulated in long-term memory through years of experience. How can The LeanMan Simulation Training Kits be used to accelerate the building of expertise?

For hundreds of years, the apprenticeship has been a favored method of training. The guild systems of the Middle Ages formalized the idea of the apprenticeship, and forms of apprenticeship are still in use today, notably in the building trades and crafts. And in all kinds of work settings, the idea of apprenticeship survives in the form of unstructured, on-the-job training. Apprenticeships provide training that's highly relevant and directly transferable to job performance. Apprentices more easily remember the job knowledge and skills they've learned because the learning has taken place in the job setting. With The LeanMan hands-on simulation exercises, each member of your team takes on the role of an apprentice.

FEATURES OF THE LEAN SIMULATION COGNITIVE APPRENTICESHIP

Feature # 1: Situated learning environment

To promote transfer, learning is "situated" in the actual job context as much as possible. Thus, Lean Factory Simulation exercises place learners into a setting typical of the job site. Likewise, the simulation should respond in job-realistic fashion. Thus, the simulation exercise produces a real product – toy wooden cars that roll freely.

Feature # 2: Problem-based learning through guided discovery

Cognitive apprenticeships support the instructional concept that learning occurs through the solution of job-realistic problems. The exercises replicate actual production situations such as nonconforming material, tool fixtures, material totes and picked kits and quality inspection criteria. Learners are given the freedom to access various sources of information about Lean Principles and to take various actions to resolve issues. To manage the workload and assure access to all key knowledge and skills, the exercises are sequenced in progressive stages to allow focus and prevent cognitive overload.

Feature # 3: Scaffolding

The key to learning is to provide resources to aid in the solution of problems. This is management of the "flounder factor" and can be provided through coaching, references, and models of best practices to name a few.   Each exercise is provided with Facilitator talking points and notes to guide the presentation of the concepts and focus direction.

Feature # 4: Naturalistic feedback and learning from errors

Typically, learners are allowed to make decisions on improvements to flow and they judge how well they did based on outcomes of the simulation. For example, in the

VSM simulation on creating an assembly work cell, feedback sources include the account on WIP, the ON-Time delivery to the customer, the time to handle nonconforming material and make decisions, and the performance change overall in the value stream caused by the point process improvement. The Lean Simulation cognitive apprenticeship is built on the philosophy that judgment errors are opportunities for learning and, unlike in the real shop, they are encouraged.

Feature # 5: Time compression

Although Lean Principles instruction can be provided in the classroom through lectures, the use of the Lean Simulation exercises to compress time and thus experience is a unique strategy to accelerate expertise. There is no substitute for hands-on experience to build expertise, and by compressing experience along with good instructional support, expertise can be built faster. Thus in the Lean Principles training, one week of lecture material is compressed into two hours of simulation.

Feature # 6: Reflection and replay

The real environment may give one the opportunity to retry a problem to see how a different approach would work, but it can be costly. The Lean Simulation cognitive apprenticeship approach encourages reflective practice by allowing for the replay of case studies by trying different options.

Feature # 7: Collaborative learning

Many years of research have shown the benefits of learners working in groups to solve problems collaboratively. In the Lean Simulation cognitive apprenticeship workers are encouraged to test each others understanding of the Lean Principles and to set up a simulation to try out each others ideas. This is an excellent way to implement group learning, and with The LeanMan Lean Factory Simulation Kits the repetitive nature of the product assembly and consistent touch labor provides realistic metrics of actual improvements to flow.

Further reading

Clark, R.C., 1998, Building Expertise: Cognitive Methods for Training and Performance Support. ISPI: Washington D.C.

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Clark, R.C., 1989. Developing Technical Training. Phoenix, AZ: Buzzards Bay Press.

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