The Surprising Principles of Learning Sciences

Abstract

Learning is one of the most powerful factors for business success. Effective learning programs increase productivity, innovation, and employee engagement. In contrast, ineffective learning programs lead to wasted resources, frustration, and loss of competitiveness. It is therefore of great importance for companies to implement the best practices known to boost learning performance. As it turns out, the principles that emerged from decades of research in learning sciences are often surprising and go against natural intuitions.

Introduction

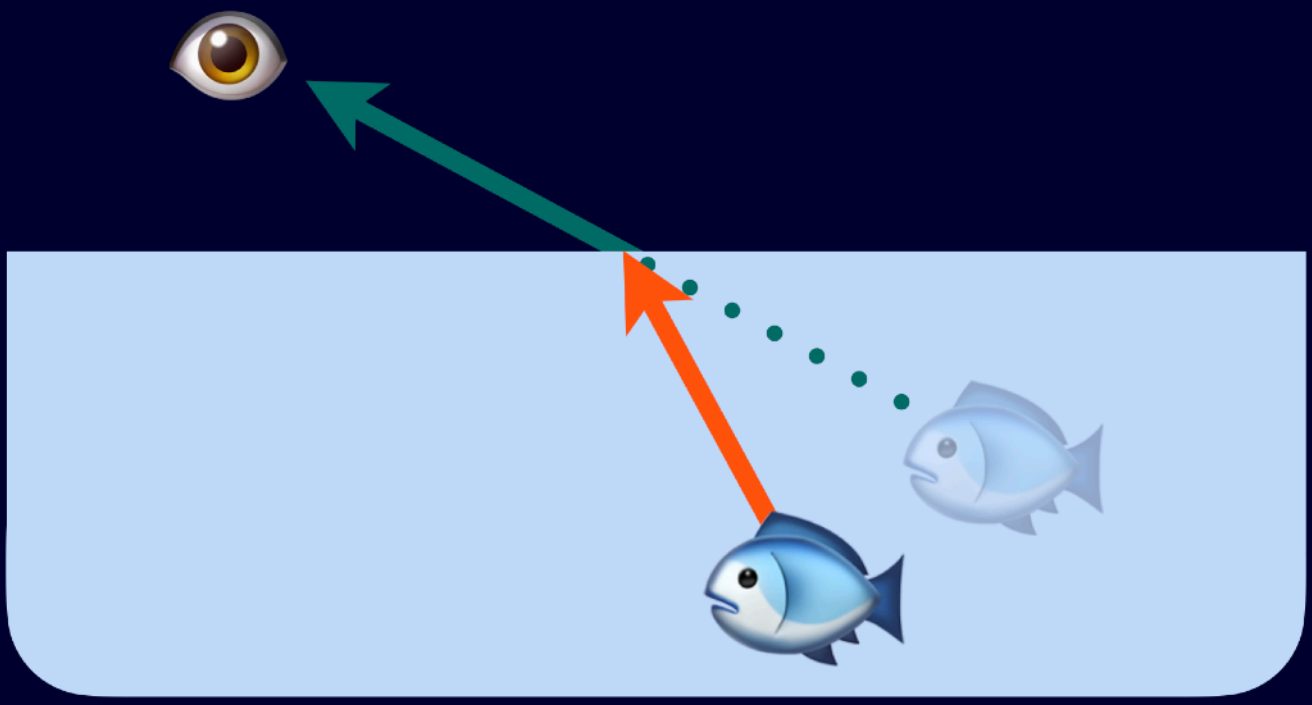
Throughout its history, science has repeatedly taught us that what we consider obvious can sometimes be quite misleading. Only a careful analysis of our implicit assumptions and their validation by systematic experiments can lead us to actually useful conclusions.

A simple example is the perceived displacement of objects in water when observed from above the surface. Due to the refraction of light at the surface of the water, an observer naively locates submerged objects higher up than they really are. To assess the situation correctly, a proper understanding of how light behaves as it passes from one medium to another is required.

Let's imagine you're spearfishing from the shore of a lake. Wouldn't you naturally aim straight at the position where you see the fish? If so, you would always miss the fish and have to survive on coconuts only. Instead, a little bit of scientific wisdom would inspire you to reject your first intuition and lower your aim. Your success rate would soar.

The subject of learning is no exception. In recent decades ***learning sciences*** have combined cognitive psychology, neuroscience, and even artificial intelligence to get to a deeper theoretical understanding of the phenomenon of learning and to improve practical instructional methods.

Most discoveries of learning sciences turned out to be pretty surprising, and the resulting recommendations are rather counter-intuitive.



Learning scientists demonstrated that many common learning practices are totally ineffective. For example, two of the most wide-spread techniques, namely highlighting and rereading, do not improve understanding. Even worse, they can even provide learners with a false sense of confidence in their mastery, which is in fact very fragile.

What this implies is that the way we naturally organize learning in our companies is probably the opposite of what we should be doing. How are we supposed to fix this? It would be very costly and laborious if every company had to systematically question its assumptions about learning and devise ways to rectify them. Luckily we don't have to do it, since learning scientists have already been researching what works and what doesn't.

Research in learning sciences is typically based on ***controlled experiments*** in which different groups of learners are submitted to conditions that differ by one major factor from each other. For example, one group was highlighting what they were reading and another group was not. Learning achievements for each groups are then measured and compared. If one group shows significantly higher achievements, the factor by which it differs is considered likely to be favorable to learning.

Once a favorable factor has been identified, independent researchers usually try to reproduce a similar experiment to validate its impact on learning. After many independent validations have been performed in many different contexts, we can become very confident in the robustness of the benefits provided by this specific factor.

Here we present some of the best principles that have been shown to have large beneficial impact on learning outcome.

Intuition??
Learning is not memorizing

Surprise!!
Learning is memorizing

But first, what is learning?

Learning programs usually aim to help their employees master ***complex skills***, ranging from hard expertise in technology, engineering, or finance, all the way to behavioral aptitudes like communication, leadership, problem-solving, critical thinking, or creativity. The obvious approach to reach such a goal is to aim straight for it and have employees practice these complex skills directly by focusing on specific use cases.

However, research in learning sciences has shown that this approach is very ineffective on its own. The recommendation is to complement it by helping employees acquire a lot of solid declarative and procedural knowledge within the subject area of the complex skill.[1,2] Here ***declarative*** knowledge refers to the mastery of relevant facts and concepts, while ***procedural*** knowledge concerns the ability to do something.

In order to be successful, the learning process has to take into account our selective attention and limited cognitive processing capacity. When trying to learn a complex skill directly, we quickly get overwhelmed by the situation with all its unfamiliar moving parts, as well as by all the potential actions that we could choose to take. This ***cognitive overload*** saturates our ability to think clearly and prevents us from making progress.

A much better approach emphasizes the importance of mastering all the relevant concepts and procedures. The resulting familiarity allows employees to reduce the cognitive load and focus on what matters the most. This makes it easier for them to identify essential features of a complex skill and to understand how to transfer it to different situations that they may encounter, beyond the specific use cases presented during practice.

The crucial role of knowledge ***memorization*** is universal and has been highlighted in a large variety of fields. For example, what makes chess grandmasters better at making optimal decisions on their next move is not some superior reasoning or creativity, but the enormous amount of patterns that they memorized.[3,4]

So to make your employees "smarter" — intellectually, practically, and emotionally — it is essential that you help them memorize a lot of relevant declarative and procedural knowledge. And of course, if you want your learning programs to have a lasting impact on performance, this knowledge has to be committed to ***long-term memory***. In fact, leading learning scientists often define ***learning*** as a change in long-term memory.[2]

Intuition??
Condense learning

Surprise!!
Spread out learning

Spaced learning

One of the most well-established principles in learning sciences states that knowledge cannot usually be acquired in one session, but only over a sequence of sessions spaced out over a period of time. This ***spacing effect*** has been known since the end of the 19th century and is now sometimes called the "golden rule of learning".[5,6]

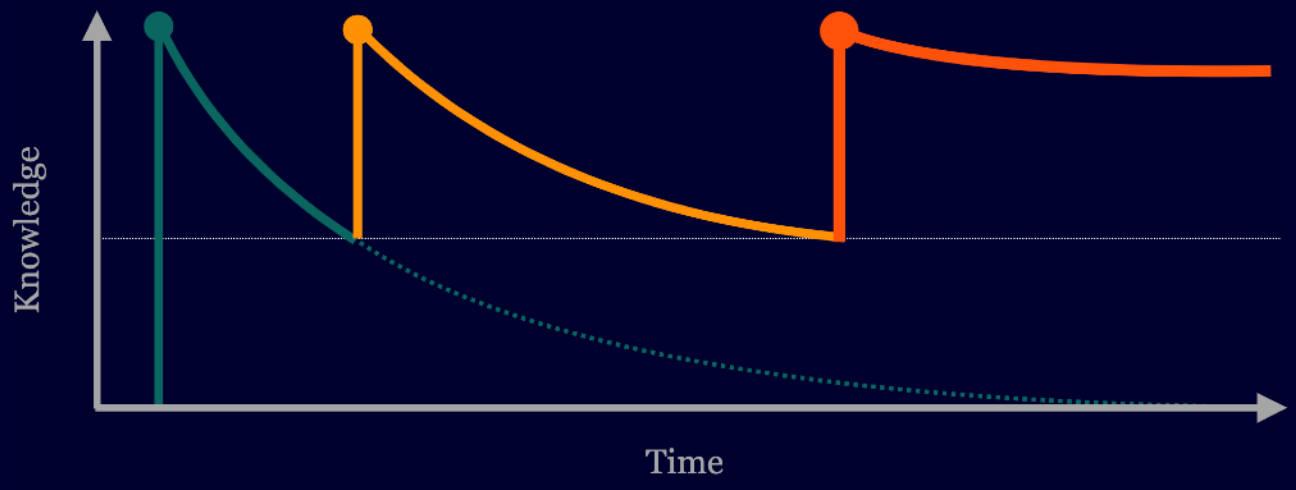
The first time we hear about a concept, our brain processes it in our ***short-term memory***. In the moment, we may feel that we have acquired it once and for all. However, if we do not encounter this same concept again in the following days, its memory trace will quickly fade away into oblivion. This is typically what happens to the information about what we had for lunch on a given day.

This is also what happens to contents introduced during a one-off learning session. By the end of the session, all participants feel much wiser and fully ready to apply new recommended behaviors to their jobs. At that point, they would all be satisfied and say that the learning session was very useful.

But their sense of mastery is delusional since it relies on information stored superficially in their memory. When a few weeks later they find themselves in a relevant situation where some recommended behavior would apply, they have unfortunately already forgotten the procedure, leaving them with no other options but to resort to old suboptimal behaviors. This phenomenon is at the root of the ineffectiveness of corporate learning.

So while it may make a whole lot of logistical sense to group all the learning sessions into a one-day seminar for all the employees, in terms of learning performance it does not. Learning should not be considered a punctual event, but rather a continuous process with recurring ***reactivations***.

Researchers have shown that if concepts and procedures are reactivated at the right moment — not too early and not too late — the speed of forgetting gradually decreases.[7] Each reactivation motivates the brain to encode concepts more robustly into long-term memory. With this approach, employees are much more likely to be able to put recommended behaviors into practice in their jobs.



Intuition??
Questions are for testing

Surprise!!
Questions are for learning

Active learning

What is the best way for learners to reactivate what they have learned? Should they just re-read what they have read initially, re-attend a seminar, re-watch a video? Not only would this be tedious, but researchers have shown that it would also be ineffective and provide learners with a false sense of security in their knowledge.[8,2]

After the initial learning event (seminar, reading, practice, video, etc.), the recommendation from learning sciences is to actively bring back each piece of knowledge to mind thanks to a ***question***. This way, employees retain their new knowledge better, and they can more flexibly retrieve it when needed in order to transfer it to different contexts.

This uncontested effect is referred to as the ***testing effect***, ***practice testing***, or ***retrieval practice***.[9,2] One crucial thing to realize here is that the term "testing" should not be taken to mean something like an exam to evaluate knowledge. On the contrary, this research indicates that knowledge reactivation with questions should be thought of as a beneficial part of the learning process itself.

Intuition??
Learn linearly

Surprise!!
Zoom in and out on increasing details

Elaboration

Elaboration theory proposes an effective way to organize learning.[10] The idea is to first start with a wide-angle overview of a subject matter, showing the major parts and their relationships. Next we zoom in on each of the major parts and understand their sub-parts. We then zoom back out to the general overview to understand how everything relates together. The zoom-in/zoom-out procedure is repeated with increasing levels of detail until the desired level of expertise is achieved.

This alternance between ***macrolearning*** and ***microlearning*** has many benefits. First, learners are more motivated because they are always aware of the "big picture" and why the different parts are important. Understanding how all topics fit together also helps learners build ***stable cognitive structures*** that will lead to long-term retention.

By switching between the overview of a complex subject and its constituent parts, learners develop a clear sense of what matters and what doesn't. This enables them to meaningfully transfer what they have learned to their actual work. When faced with a complex situation, they are able to identify its relevant constituent parts and recognize that they are in correspondence with those of a use case that they have learned about. By zooming out they recall the big picture and are in a good position to apply their new skills.

Intuition??

Learn one subject after the other

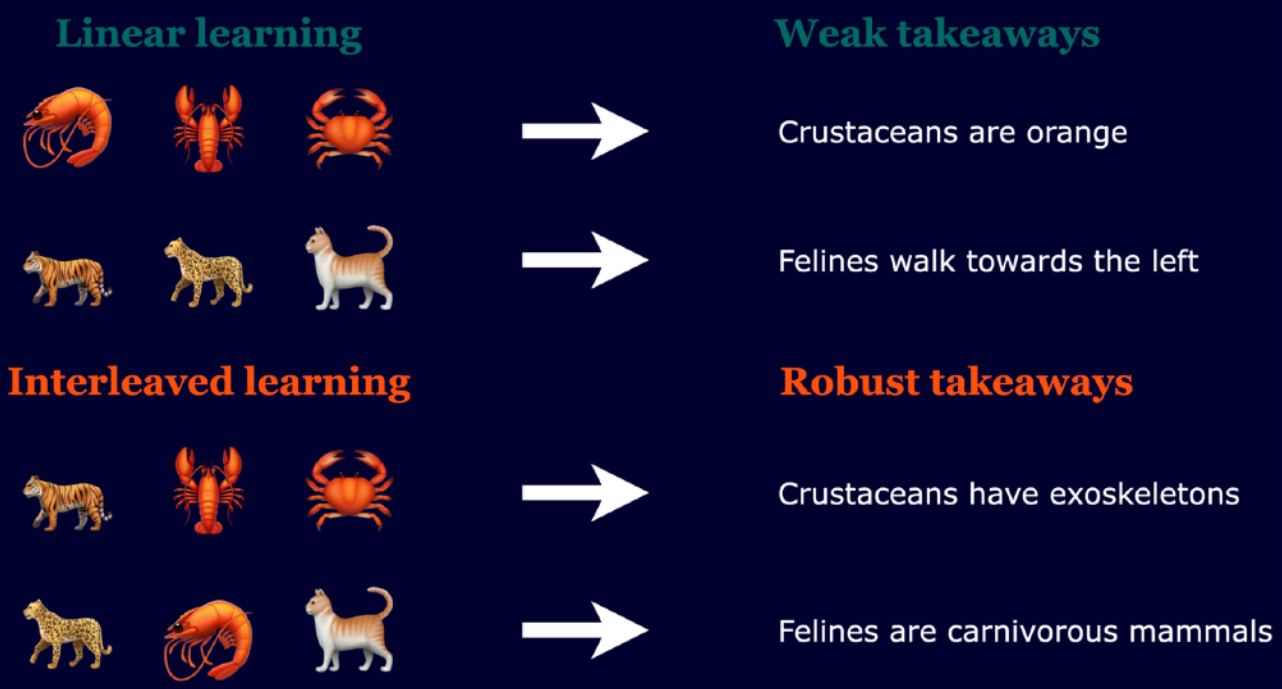
Surprise!!

Mix up subjects

Interleaving

Imagine that you need your employees to master 3 different strategies, denoted by A, B, C. An intuitive approach may be to organize 3 seminars, each of which dedicated to a thorough discussion of one strategy: AAA, BBB, CCC. After each seminar your employees may feel a strong sense of mastering the corresponding strategy. Experiments however suggest that their grasp of the 3 strategies is quite weak and ephemeral. They would also have a lot of difficulty in applying the 3 strategies to new situations that were not explicitly covered in the seminars.

A more effective approach is based on ***interleaving***, that is mixing up learning contents. So the contents of the 3 seminars would become for example: ABC, ACB, BAC. Research showed that this leads to vastly superior performance.[11,8] Interleaving encourages employees to build more robust encodings of the 3 strategies that focus on the most relevant aspects of each one of them and discard anecdotal details. As a result, employees can more effectively recognize when one of the learned strategies applies to an actual work situation that they may face.



Intuition??

Not all learners can excel

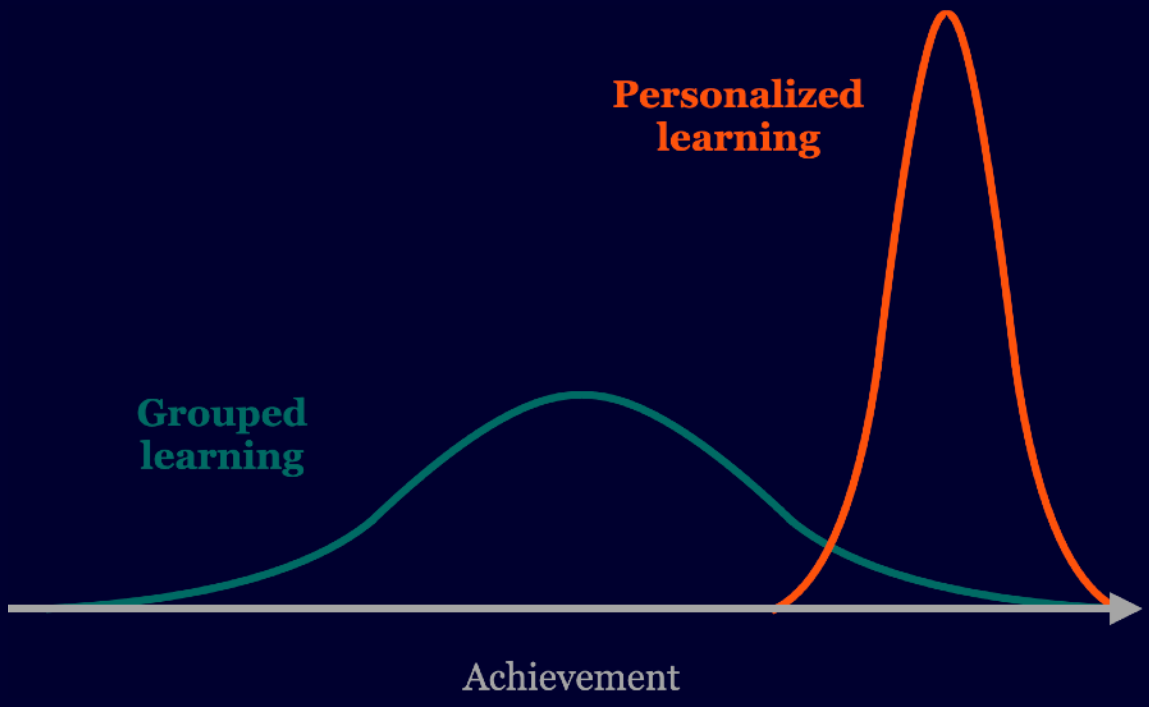
Surprise!!

All learners excel with personalization

Personalization

Personalization is often called the "holy grail of learning" because it has been shown that learners who receive personalized one-to-one tutoring perform better than 98% of learners who receive uniform training in a group. This is an enormous effect![1,2,2]

An interesting observation is that not only is the *mean* achievement much higher with personalized learning, but the ***variance*** between learners is also reduced. This means that pretty much all learners have the potential to reach impressive levels of learning thanks to personalization.



Learning scientists therefore advocate for a form of learning that is personalized to the needs and abilities of individual learners based on their performance. In consequence, the principles that we have described above only reveal their full power when they are implemented in a personalized way.

For example, spaced learning should not simply be based on some fixed rules such as doubling the amount of time until the next reactivation. Rather, reactivation dynamics should be personalized and take into account the ***unique characteristics*** of each learner: background knowledge, memory abilities, motivations, etc.

Conclusion

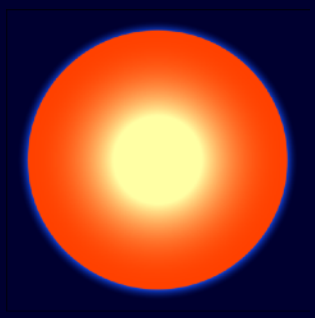
This article gave a brief overview of many surprising principles discovered in learning sciences thanks to systematic experimentation and analysis:

- Learning is memorizing
- Spread out learning
- Questions are for learning
- Zoom in and out on increasing details
- Mix up subjects
- All learners excel with personalization

The fact that they are rather counter-intuitive should encourage us to deeply question our decisions when designing learning programs for which we are responsible. Only if they are in accord with these principles can we achieve our vital objective to help employees actualize their full potential.

About the author

Maxime Gabella studied philosophy and art before turning to theoretical physics. He obtained a Master's from EPFL and a DPhil from the University of Oxford. He then directed research programs in many top institutions in Europe and in the United States, such as the Institute for Advanced Studies in Princeton. He has published 20 papers in high-impact scientific journals on string theory, mathematics, and artificial intelligence. He founded the startup MAGMA Learning in 2019 in Lausanne, Switzerland, with the mission to enhance human learning thanks to machine learning.



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