UNIVERSITY OF CAMBRIDGE

The constructivist perspective on learning

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https://science-education-research.com

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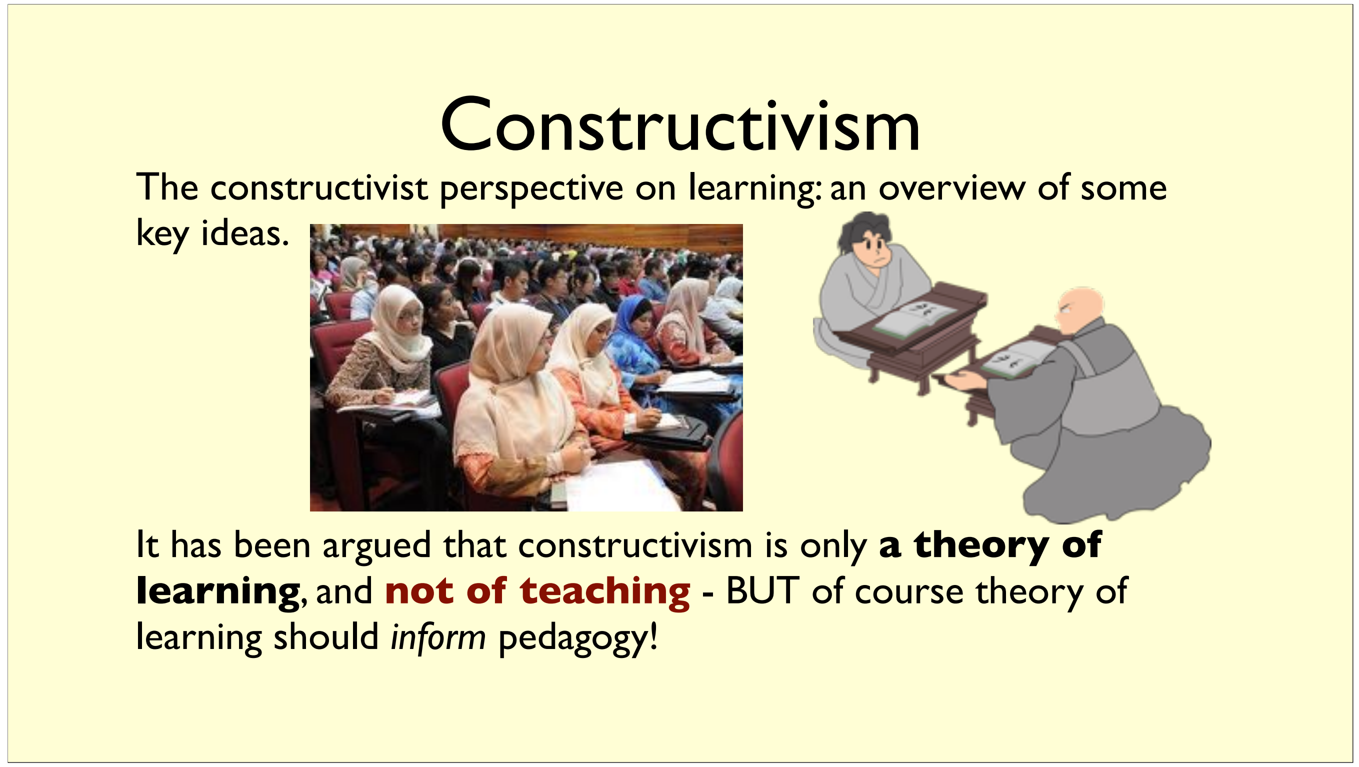
Thank you for inviting me to talk to the Faculty again today. I hope you are all well and safe this afternoon, or indeed this morning as it is here in snowy Cambourne.

In this lecture, I will consider the constructivist perspective on learning.



There are various ‘versions’ of constructivism - the aim here is to give an overview of some key ideas.
[https://science-education-research.com/constructivism/]

Constructivism is sometimes used as a label for ideas relating to approaches to research, and understanding knowledge construction in the disciplines
[see, for example https://science-education-research.com/publications/miscellaneous/constructivism-good-bad-abhorrent/] - here the focus is on personal learning.

It has been argued that constructivism is *only* a theory of learning, and not of teaching - BUT of course a theory of learning should inform pedagogy!

Therefore in this lecture I will offer a perspective on learning, and this will be followed-up in the subsequent lecture on teaching.

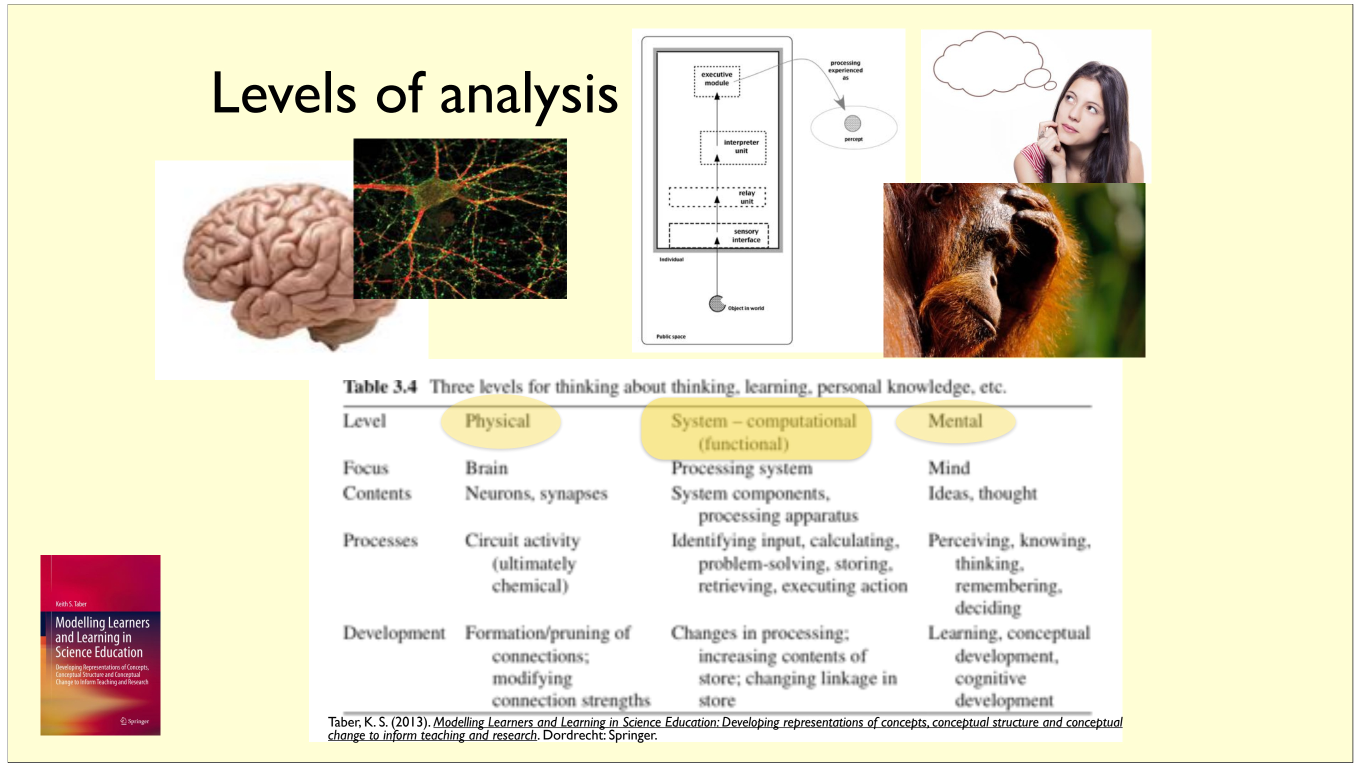


Table 3.4 Three levels for thinking about thinking, learning, personal knowledge, etc.

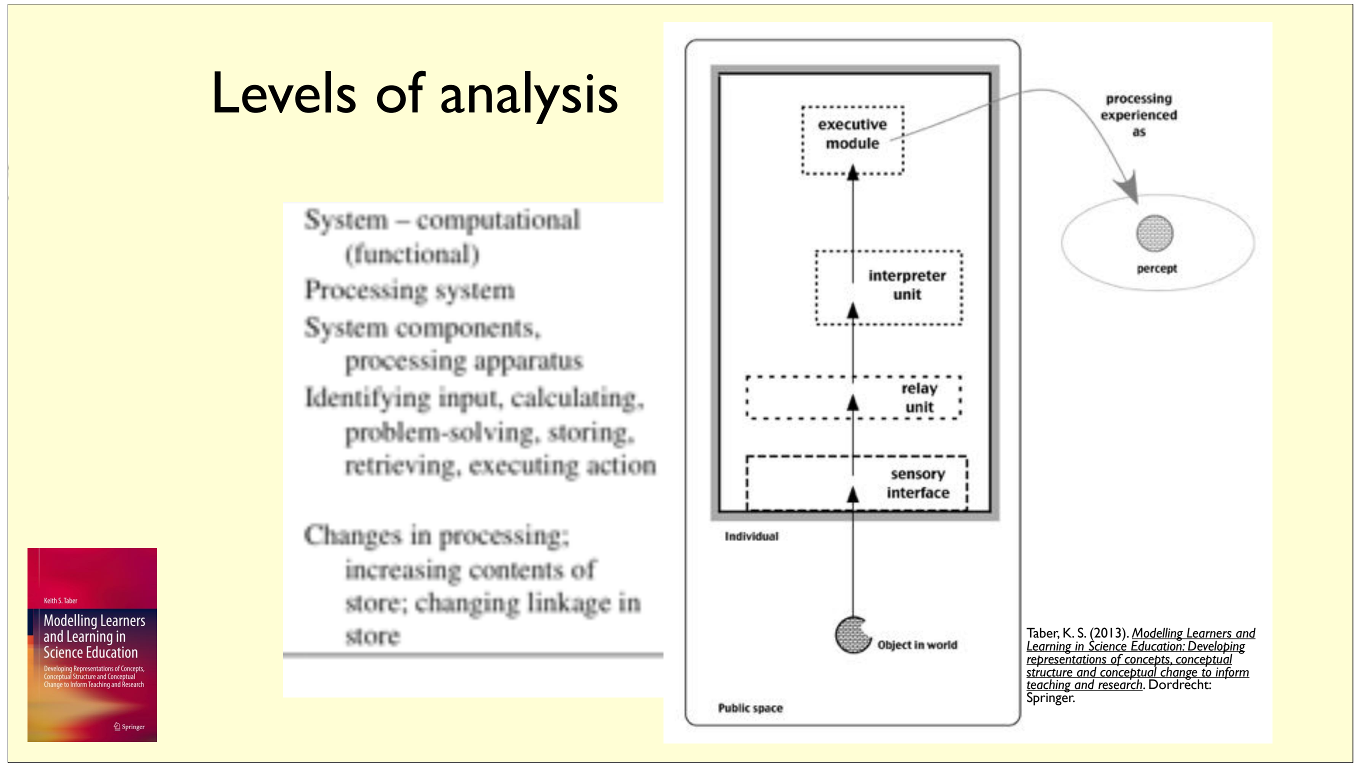
Level	Physical	System – computational (functional)	Mental
Focus	Brain	Processing system	Mind
Contents	Neurons, synapses	System components, processing apparatus	Ideas, thought
Processes	Circuit activity (ultimately chemical)	Identifying input, calculating, problem-solving, storing, retrieving, executing action	Perceiving, knowing, thinking, remembering, deciding
Development	Formation/pruning of connections; modifying connection strengths	Changes in processing; increasing contents of store; changing linkage in store	Learning, conceptual development, cognitive development

We can think about learning, and indeed cognition in general, at a number of levels [https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/].

We can use the language of 'mind', which is the way learning tends to be discussed in everyday language using notions such as thinking, learning, remembering, forgetting, and so forth. Although we use these terms a good deal in education, they are often not well defined, but tend to have rather diffuse meanings.

In everyday social discourse diffuse meanings can be positive, as they facilitate normal conversation. In technical settings, such as research or the professional discourse of teachers, however, we sometimes need to be precise about what exactly we mean by such things as learning or knowledge or intelligence.

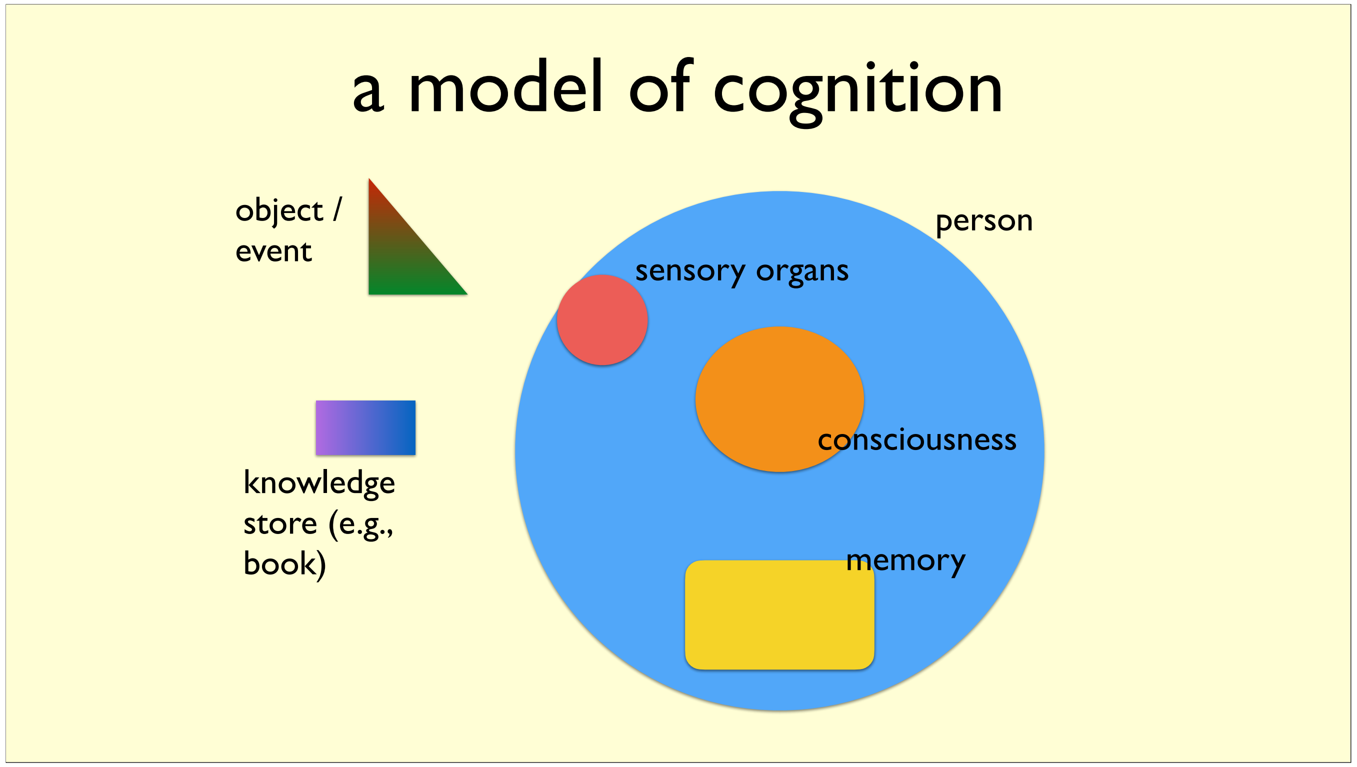
Another level we can talk about is physiological. We can talk about the brain, and its neurones, and their synapses, and how these might form circuits. I do think that cognition is ultimately based on activity at the neuronal level, but also that this is often not the most useful level for talking about learning when seeking to inform teaching. I am sure we will learn much from neuroscience in the future, but doubt it will ever be useful for teachers to talk about teaching and learning in practical situations in terms of neurones and synapses and neurotransmitters - even if in principle we could reduce all aspects of learning to such matter. A third level would be to consider a learning system in the abstract.



That is, to treat the learner as a system which has components and through which information is passed and processed, without worrying too much about the physiological and anatomical details of the system.

There is a danger there that because we can draw system diagrams for human learners and computers which look very similar we become seduced into treating them as equivalent. Computers and humans have analogous features, but in some ways are very different. I will use systems models in this talk, but please remember they are just models - ways of representing something complicated in a fairly simple way. As has often been noted, all models are simplifications, and therefore all models are in a sense wrong!

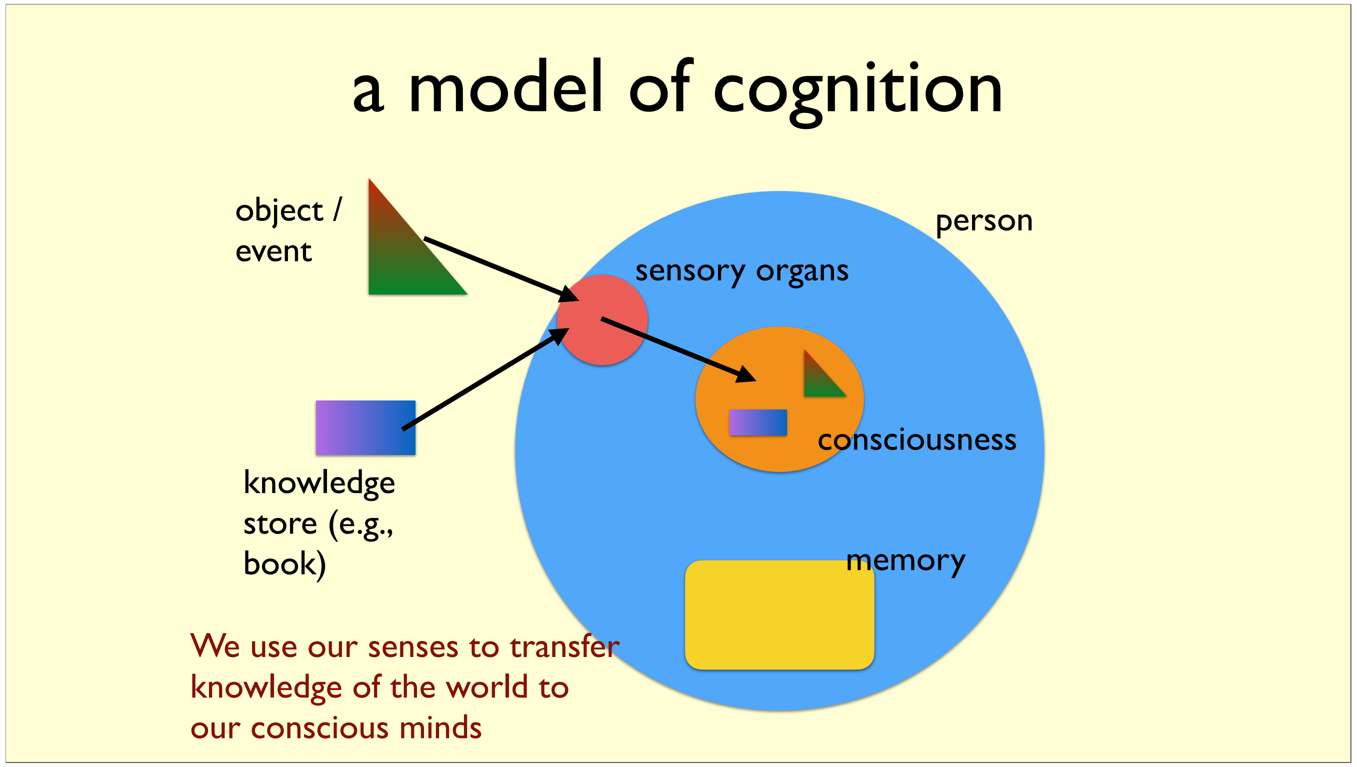
Learning can be described in these different ways, and they are not alternatives that we must choose between, but complementary descriptions that we can select according to when they are most useful.



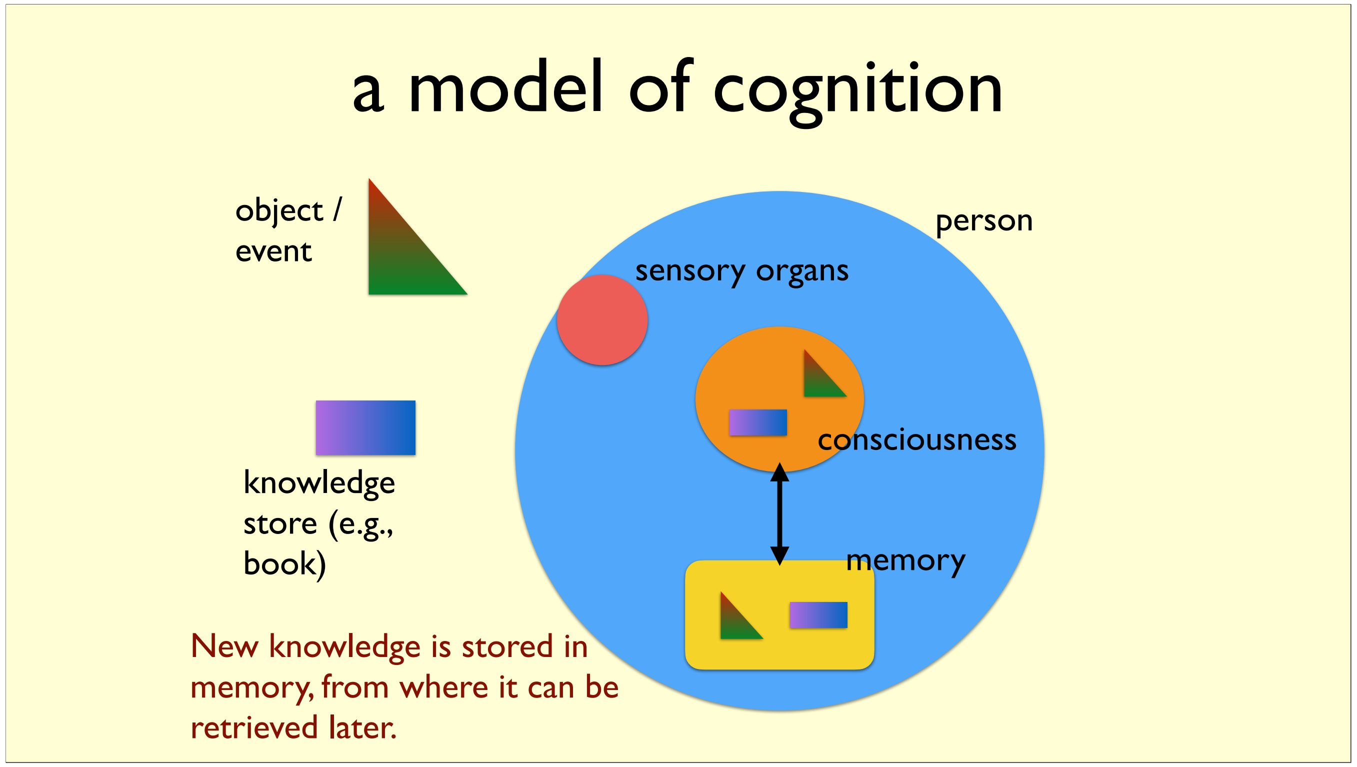
In this lecture the system I will focus on is a learner. However, in a subsequent lecture I will talk about the system of teacher and learner.

When analysing a situation we can choose where to draw the line around the system according to what is most useful for current purposes. However, we should keep in mind that a learner is always embedded in a wider context. For much of today's talk it will be useful to see a learner as a system, and everything outside the learner as its surroundings. BUT sometimes it is more useful to see a learner and teacher as the system, or a pair of learners as the system, or a group, or a whole class. But for today, I am mainly dealing with some basic characteristics of the individual learner.

So, here is a really simple model of a learner as a system, and I've picked out some system components. The system has sensory organs - eyes, ears etc. - a memory, and a central processing component where conscious thinking takes place. The learner can sense the world, and has conscious awareness, and this include some awareness of previous experience - due to prior learning.

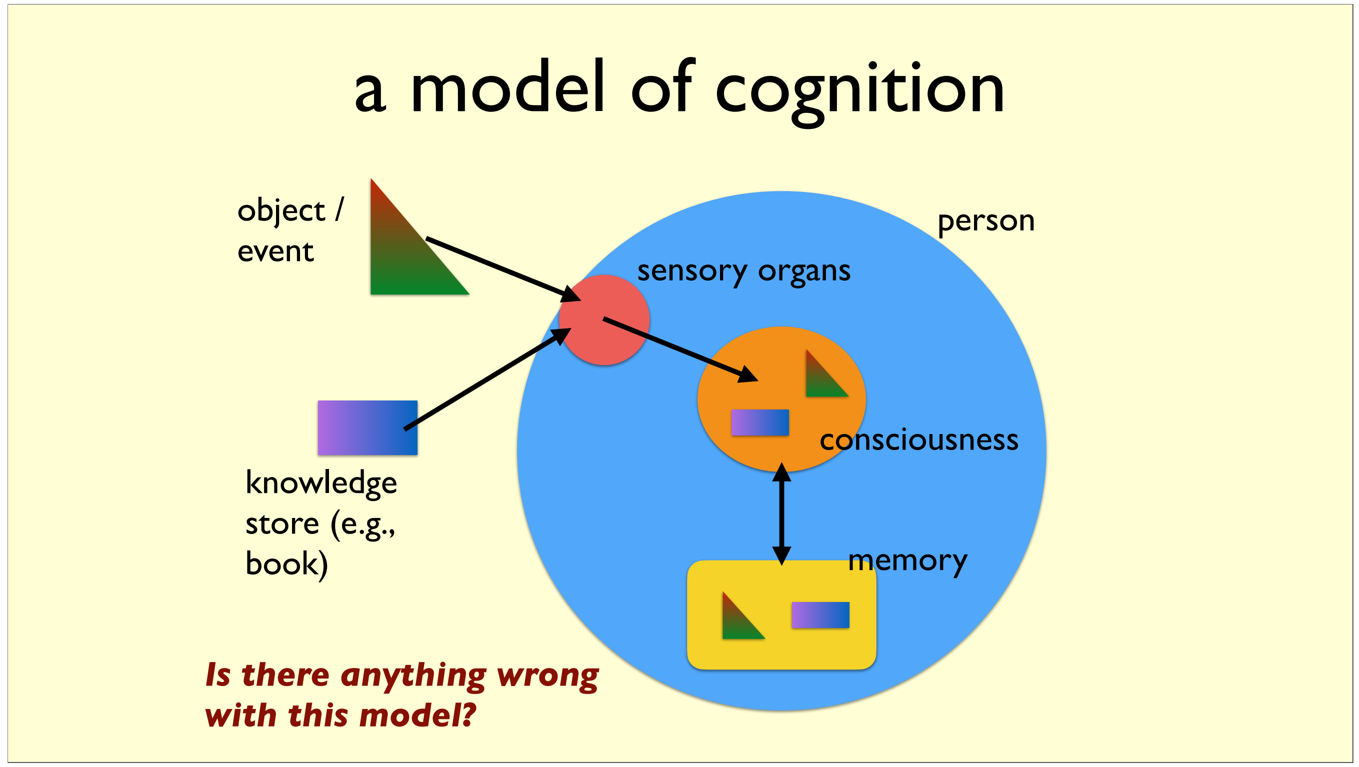


A very simple way of thinking may be that the sense organs somehow capture an impression of what is outside the system - objects, events, texts and so forth - and pass this into consciousness.



It can then be transferred into memory.

And later brought out of memory to be remembered.



So this is a very simple model, and if cognition was as simple as that there would be little need for a constructivist model of learning. You will probably not be surprised to find I am going to suggest this model is not only a simplification, but that it can sometimes be a very misleading one.

This is an important point, because from the time we are very young we tend to talk about perception, and learning, and memory, as if the system is this simple: that we gain knowledge of the outside world simply by observing, and then we can often somehow store that knowledge in memory for when we wish to retrieve it.

If only life was that simple, and learning about the world was so automatic. If it was, we probably would not need skilled and trained teachers - or indeed schools and universities. However, I think there are good reasons why we have not been equipped with cognition which works in such a simple way.

Learning?

what is learning

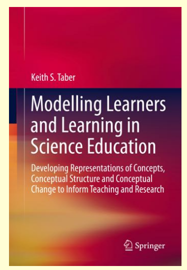
?

As this lecture is about learning, it might be useful to check if we agree on what learning is.

We might think that learning is acquiring knowledge (including knowledge how to do things, skills) but I will suggest a different approach.

Learning

a change in the potential for behaviour



behaviour?

*why a change **in potential**?*

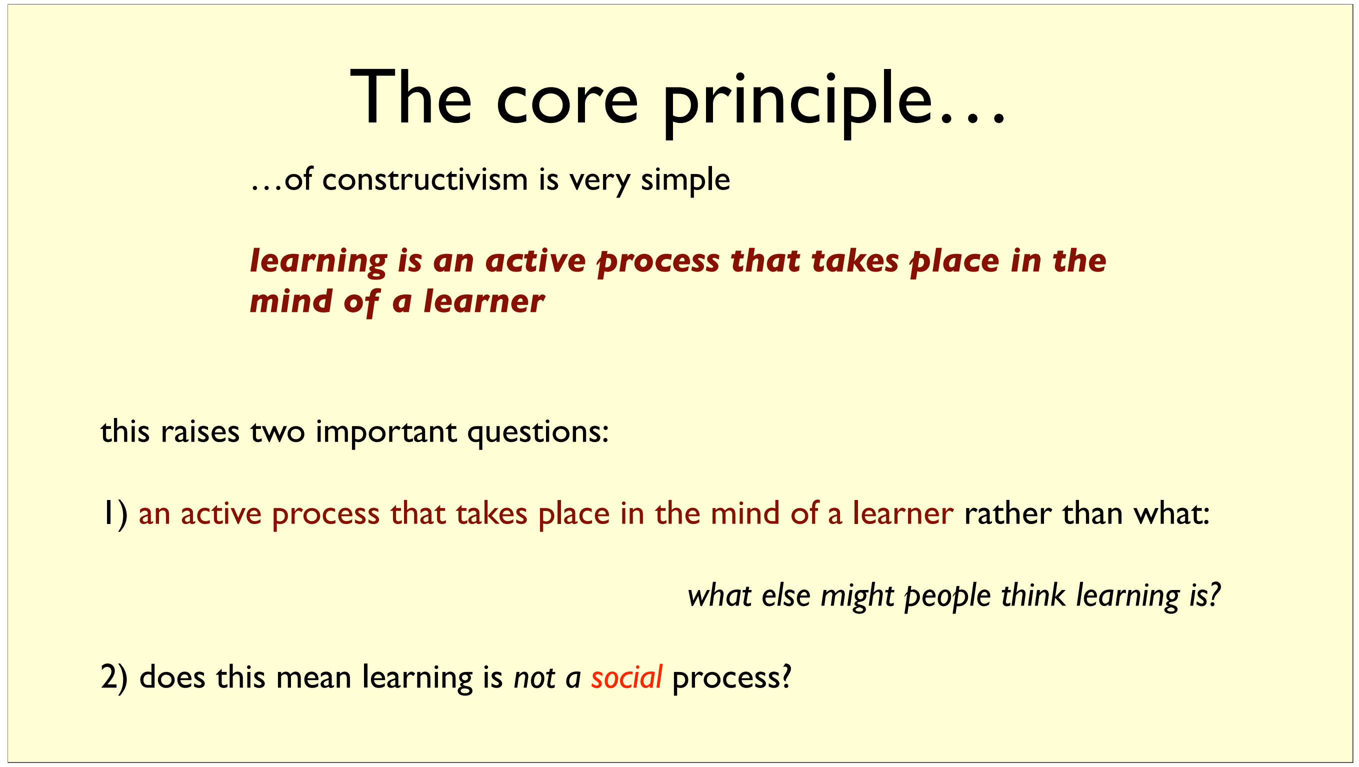
an argument for this definition can be found here

I have suggested it might be useful to see learning as a change in the potential for behaviour [https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/].

I intend behaviour in the widest sense - so this includes verbal behaviour. As a simple example, to say that someone had learnt that Paris was the capital of France might mean they now had the potential to correctly answer the question '*which city is the capital of France?'* after learning, when they had not had this potential before.

Of course, if they are never asked, they may have no reason to express that learning, which is why I refer to a potential. Even before learning this they might have guessed correctly - although if they did guess 'Paris' we might suspect that they must have previously learnt something sufficiently relevant to make such a lucky guess.

In other words, learning can be subtle and assessing learning is not straightforward.



The core principle of constructivism is very simple. Learning is an active process that takes place in the mind of a learner. [https://science-education-research.com/constructivism/]

This raises two important questions:

Firstly, learning is an active process that takes place in the mind of a learner, *rather than what*?
That is, what else might people think learning is?
Secondly, does this imply learning is not a social process?

does this mean learning is ***not*** *a social* process?

Usually learning is (at least indirectly) socially mediated…

…but

Our starting point will be to focus on ***the learner***, and treat *everything* around the learner as a part of ***their environment***

Usually in humans learning is usually, at least indirectly, socially mediated…but our starting point will be to focus on the learner, and treat everything around the learner as a part of their environment

Our starting point will be to focus on the learner, and treat everything around the learner as a part of their environment

Does that sound like the approach of any theorist you 'know' about?

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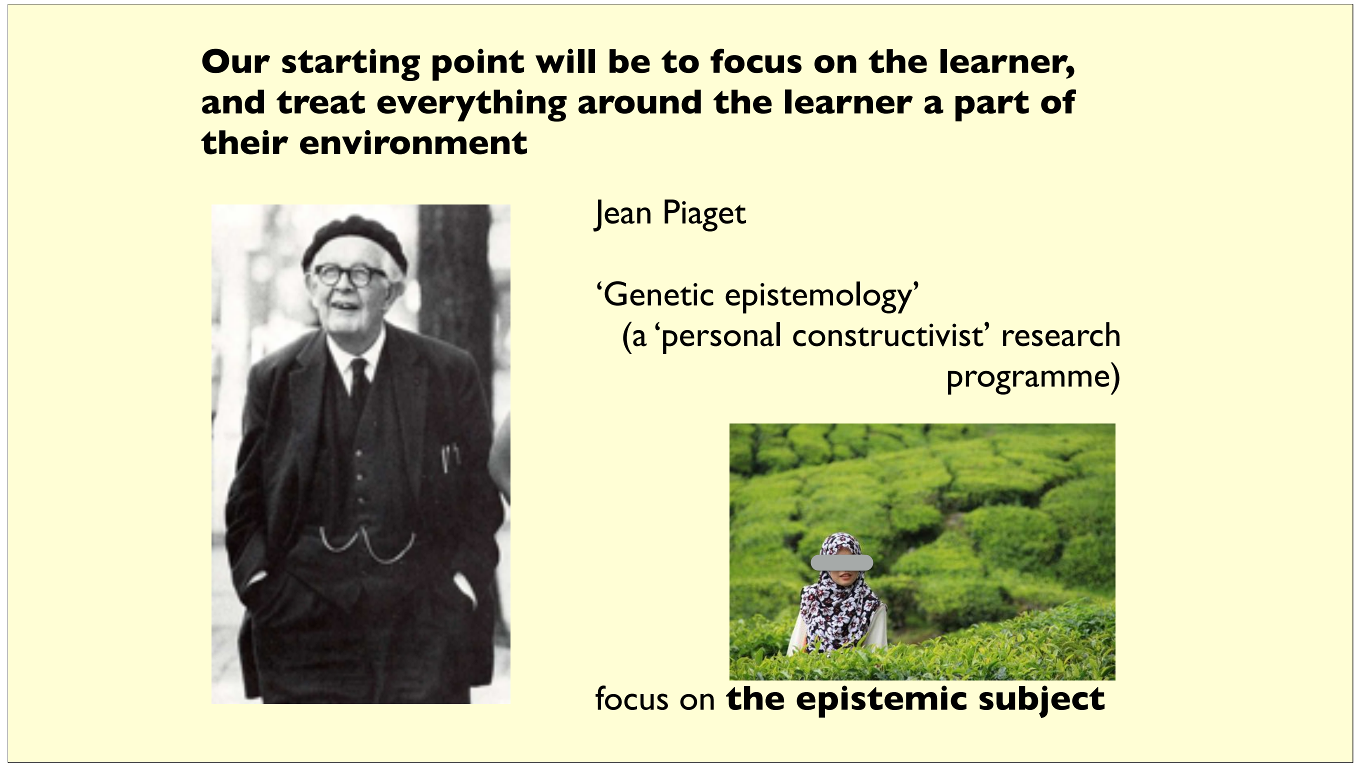
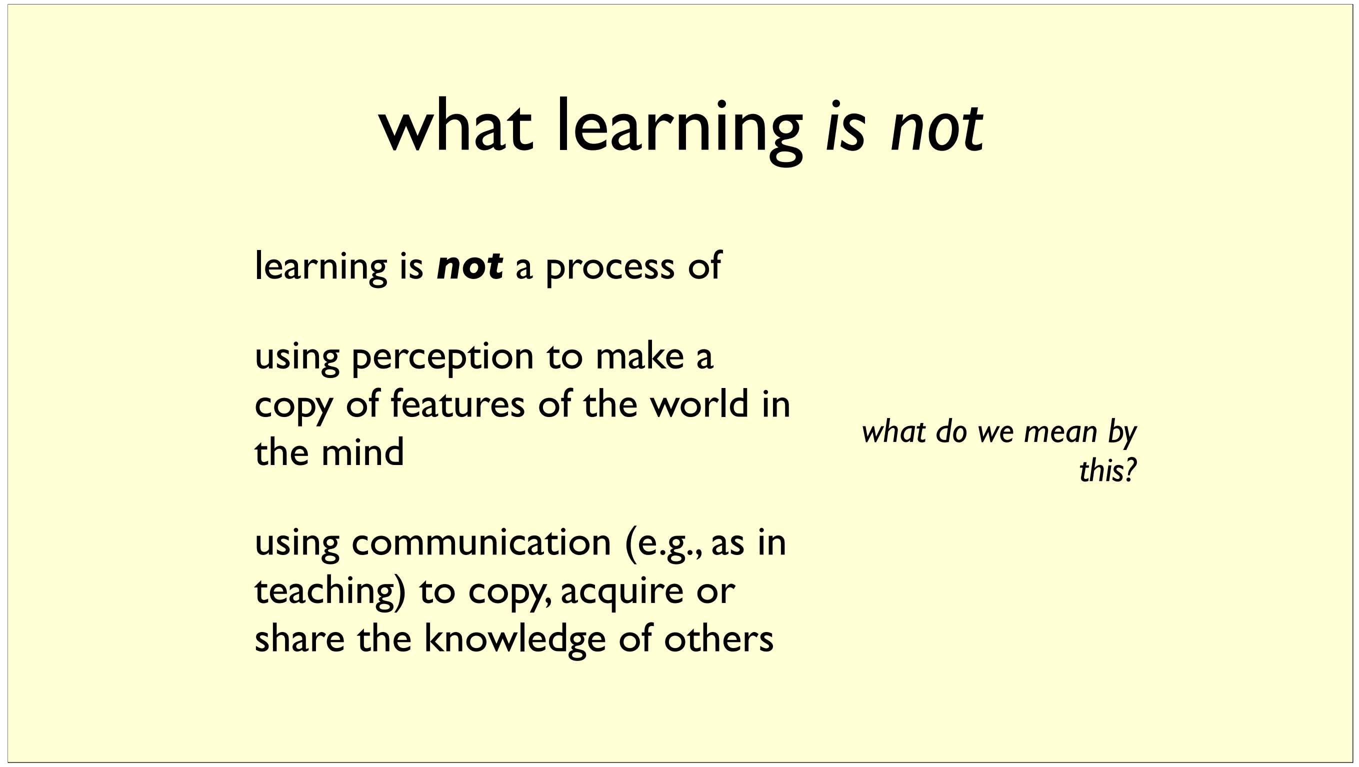


That approach may have reminded you of the work of Jean Piaget, who described his programme of research into cognitive development as 'genetic epistemology'.

This work is now recognised as being constructivist in nature, as I will explain. It is considered 'personal constructivist' rather than 'social constructivist' because of the focus on the epistemic subject, a kind of typically developing human individual.

Piaget actually recognised the importance of social interactions in development and learning, but for his own research purposes often treated others around the epistemic subject as simply parts of the learner's environment. This has often been seen as a bias against the social aspects of learning, but I think it was more a pragmatic simplification, given how little was known about this area of work when Piaget started his programme.



Getting back to the question of '*what else might people think learning is?*', I am going to argue that commonly people adopt a very naive model of learning. Although this is over-simplistic, it is so embedded in our language, that we often simply take it for granted.

This model involves learning about the world as a process of using perception to make a copy of features of the world in the mind, and of learning from others, as in teaching, using communication to copy the knowledge of others.

That is problematic - but before we discuss why, we should just reflect on a term I have used there - knowledge.

before we proceed: a quick word about 'knowledge'

We all know what 'knowledge' is

Knowing is one of the those terms ('the mental register')

thinking, knowing, believing, imagining, understanding…

that we all use about mental processes all the time.

Obviously everyone knows what knowledge is, and especially everyone in Universities. After all, the main purpose of the University is to develop and disseminate knowledge - so we must all, surely, agree on what it is?
[https://science-education-research.com/constructivism/knowledge/]

knowing

"a little knowledge is a dangerous thing";

"I used to know that";

"you know nothing at all about my life!";

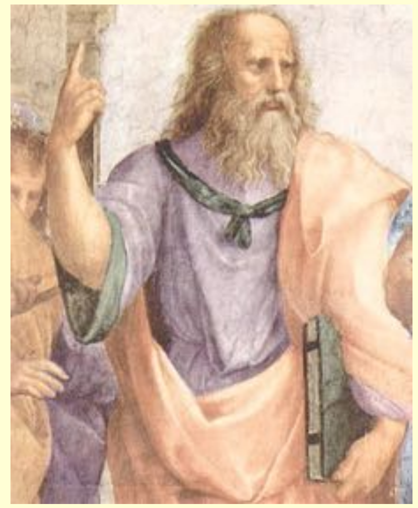
"she knows…";

"I'd like to know you better"

So what do *you* understand by knowledge?

We use the term often enough.

Knowledge



"Traditionally,
knowledge has
been defined as
justified,
true
belief"

Bhaskar, 1981: 128

Bhaskar, R. (1981). Epistemology. In W. F. Bynum, E. J. Browne & R. Porter (Eds.), *Macmillan Dictionary of the History of Science (p. 128). London: The Macmillan Press.*

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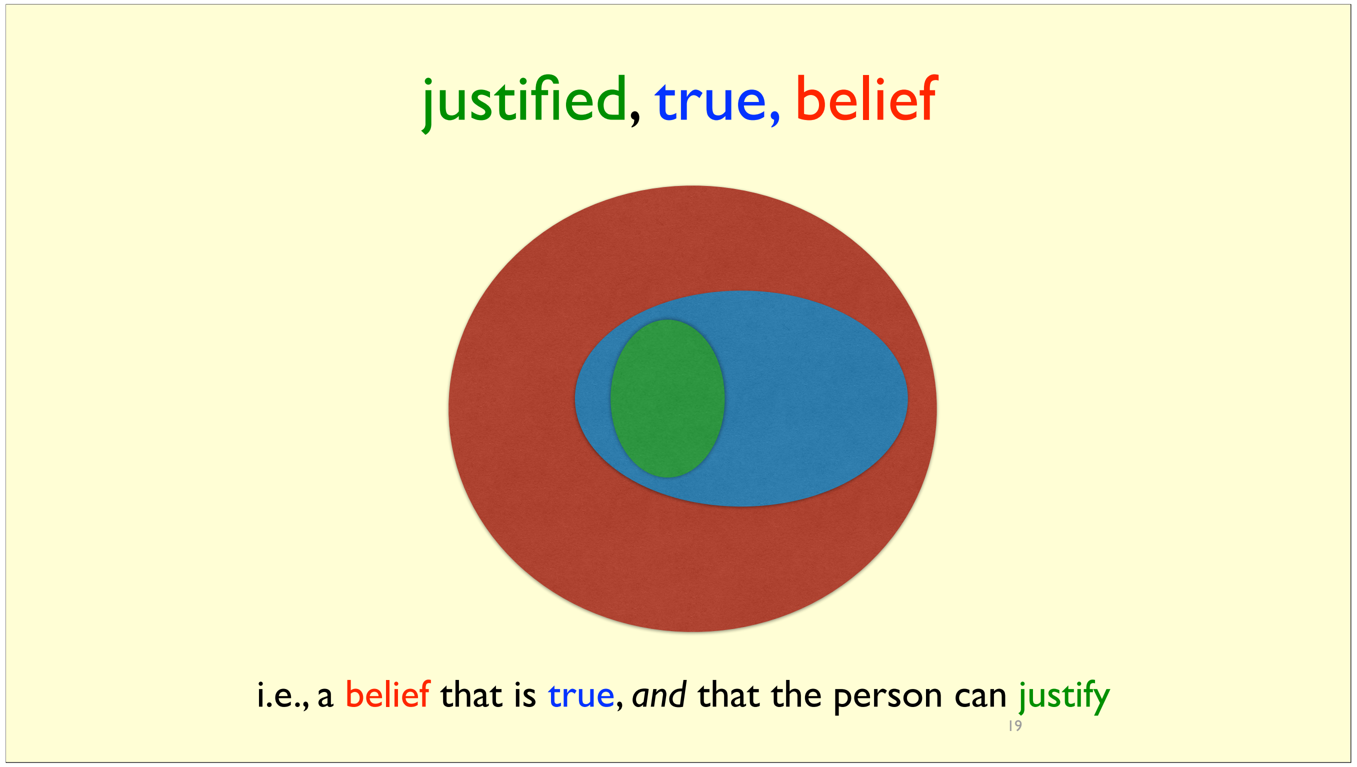
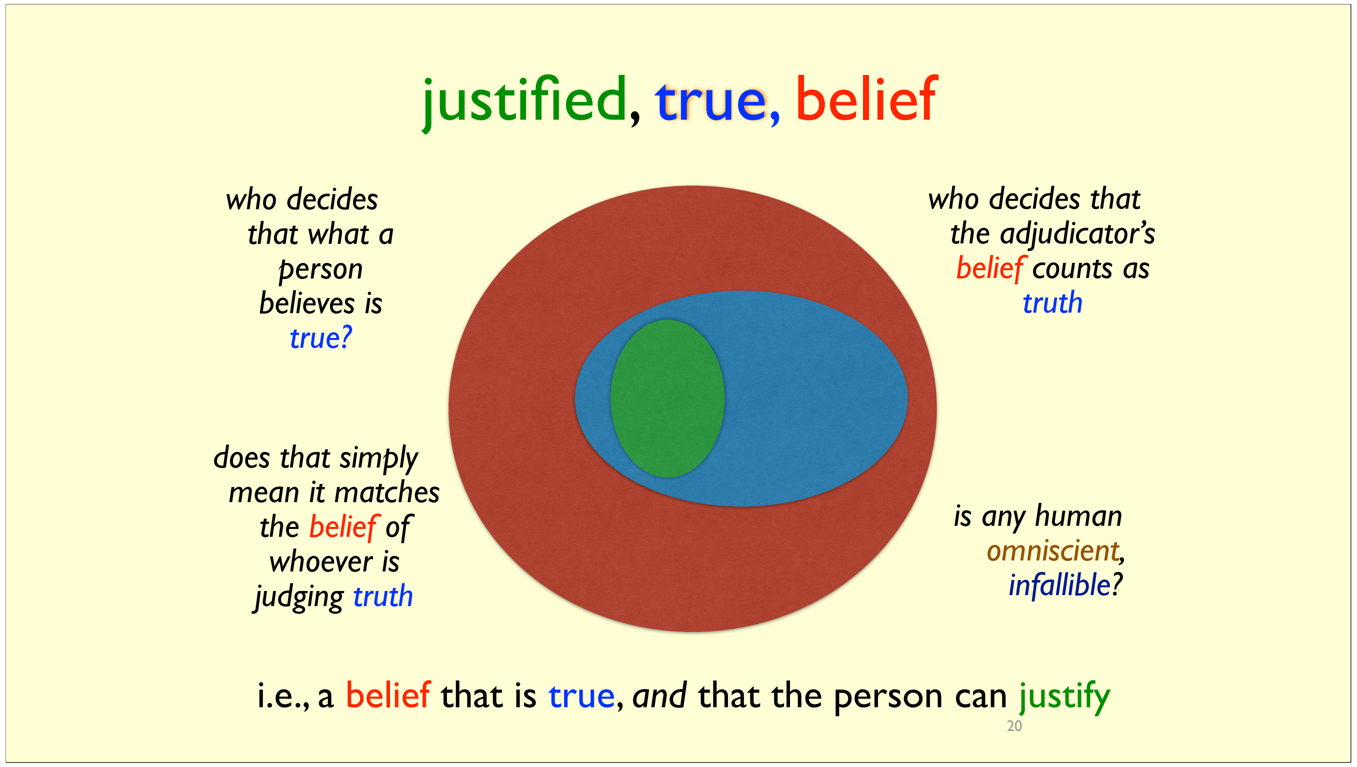
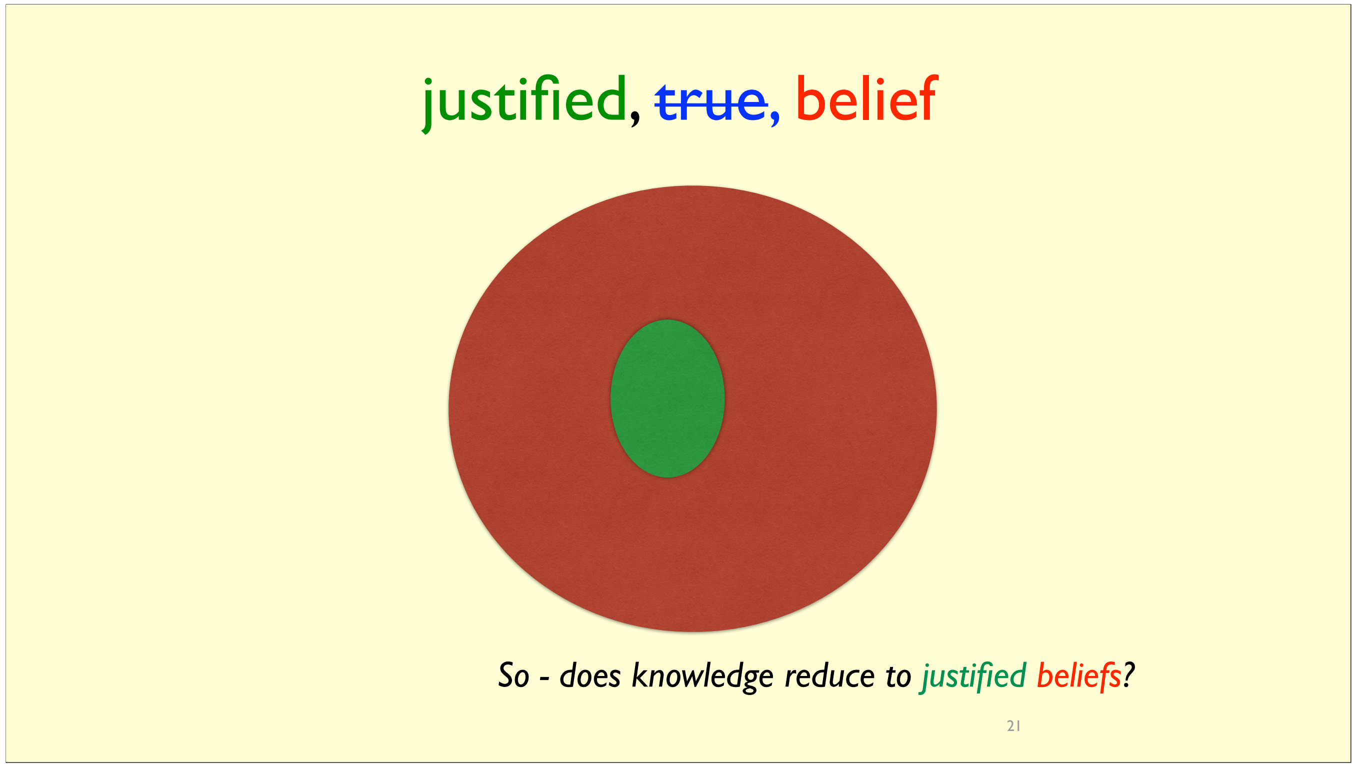


That is, a belief
that is true,
and that the person can justify.

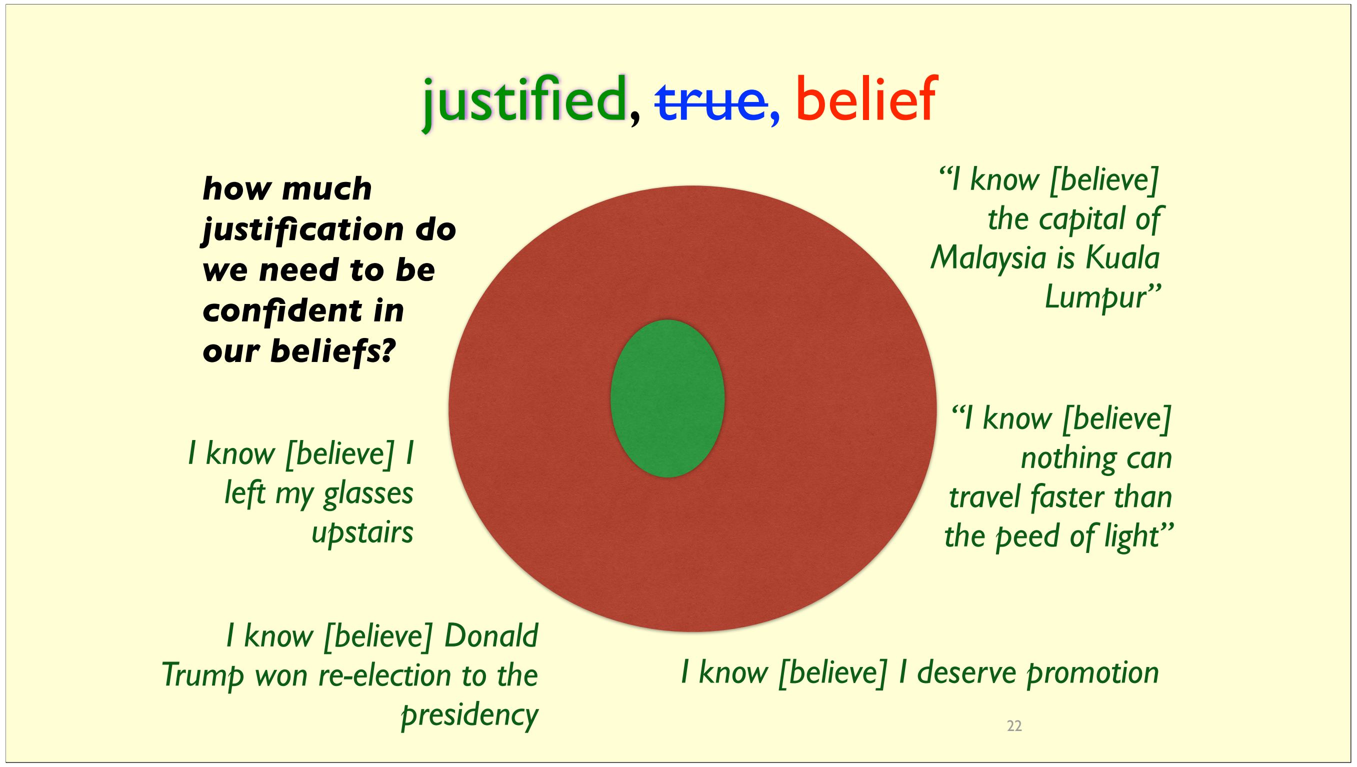
This seems simple enough, until we probe a little.



Because if something is only knowledge if it is true, then we need to know what is true.
Which seems to be the same as saying that we need to already have certain knowledge before we can know we have knowledge (or recognise knowledge in another).
Teachers are expected to tell students whether their knowledge is canonical or not - but how do teachers know? Did their own teachers have to judge this for them? And how did *they* know?
To put it another way - which of us can be sure we know all the answers, and can judge someone else's knowledge as genuine or false.

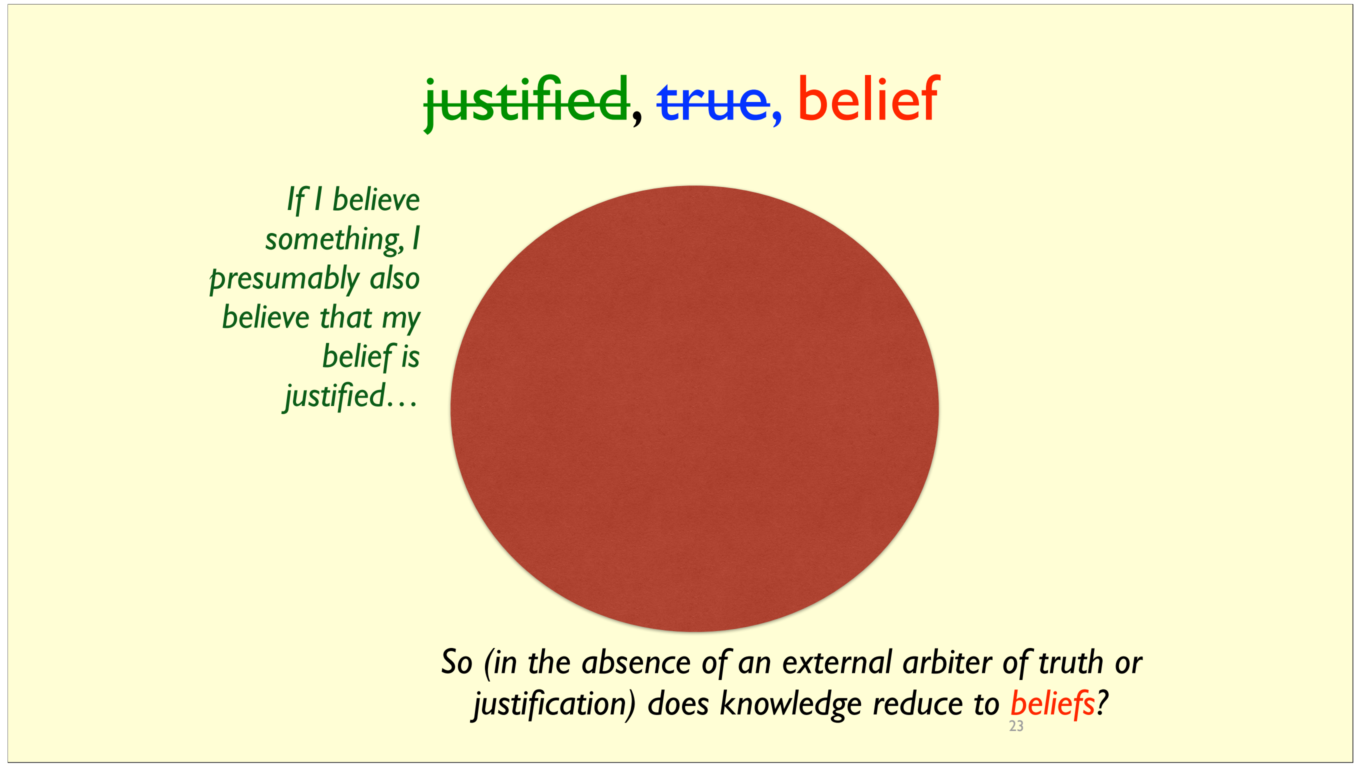


But if we do away with ‘truth’ as a criterion, then knowledge is reduced to just justified belief.



Which is fine as long as we know what justification is sufficient to know that we have knowledge - who judges the justification?

This seems to be a variation on the same problem - that we need some infallible, omniscient arbiter.



If we are not careful, we are just down to what people believe as being knowledge.

Which is fine, as long as we bear in mind that people can be wrong, different people think different things, and we can all change out minds. So, what we are left with does not sound much like knowledge in the traditional sense, but perhaps in education is all we have to work with!

The idea of true, justified, beliefs is useful to philosophers, but in education and everyday life it is not very helpful.

The nature of (what we usually mean by) ‘knowledge’

“We guess, have hunches, and believe on such evidence as is available,

and for the time being we take what we believe to be true without, however, claiming certainty for our beliefs.

If we are wise we go on testing our beliefs, searching for further evidence that will confirm or refute them.

A great deal *of our* ***knowledge*** clearly is of this kind and it has been held that ***all*** of it is so.”

(Aaron, 1971, p. 49, emphasis added)

Aaron, R. I. (1971). ***Knowing and the Function of Reason***. Oxford: Oxford University Press.

I rather liked this comment on knowledge.
[“We guess, have hunches, and believe on such evidence as is available,
and for the time being we take what we believe to be true without, however, claiming certainty for our beliefs.
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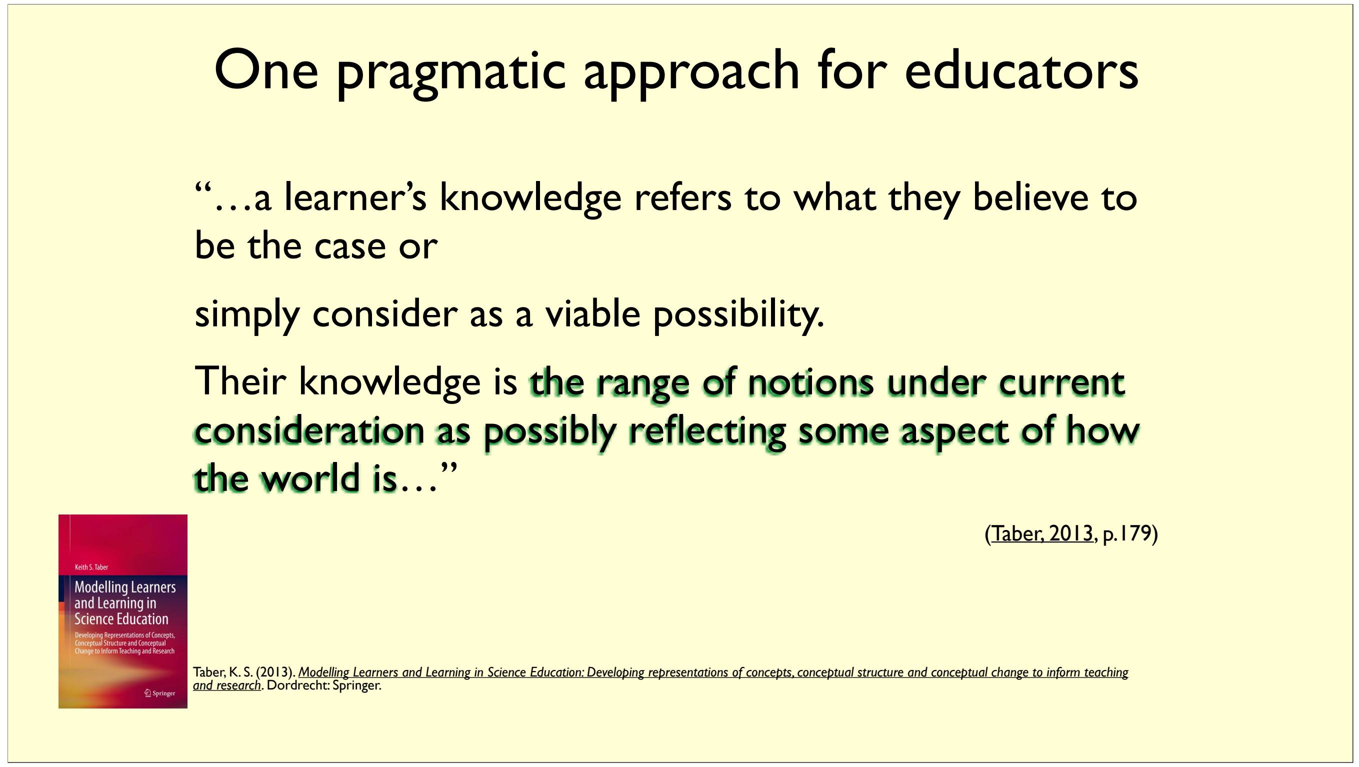
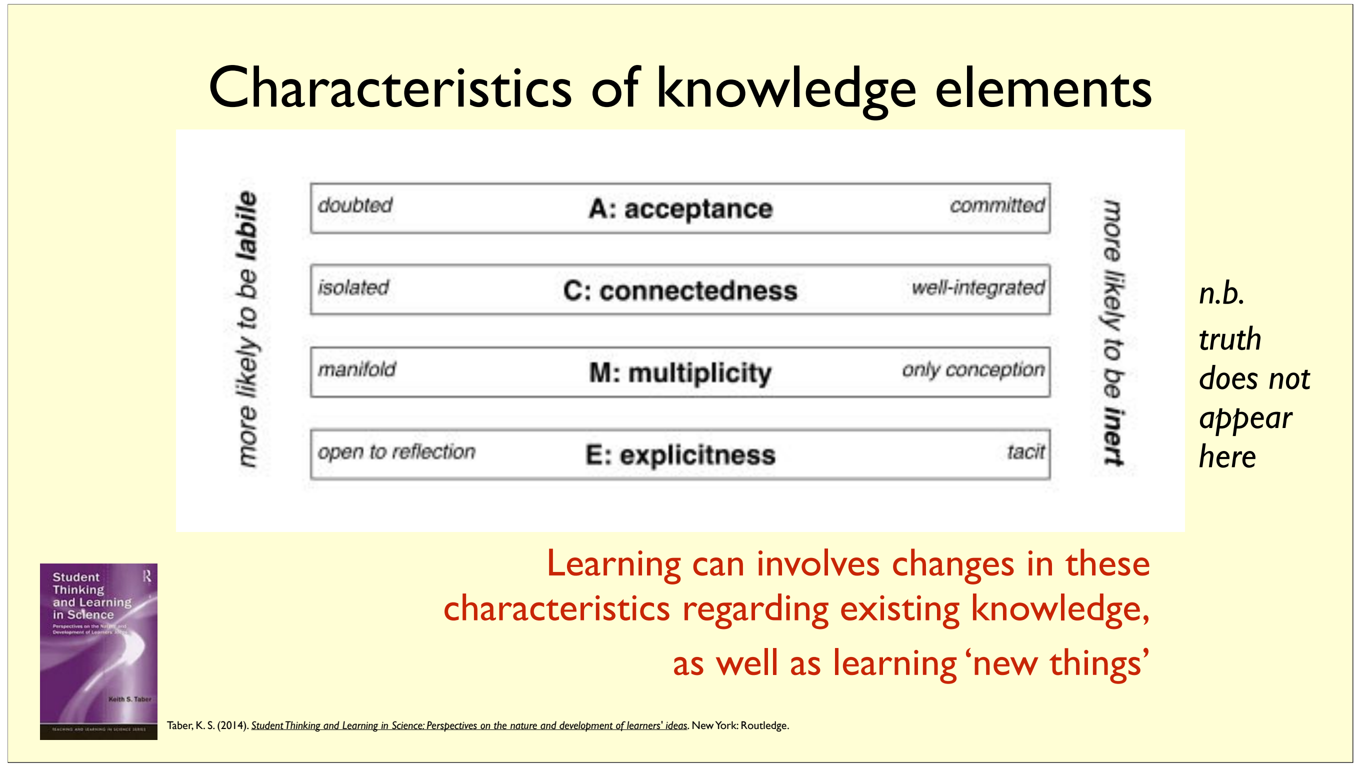


So in education when we are a dealing with learners' knowledge this is in practice just the range of notions that person has under current consideration [https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/].

Else, if we prefer to stick to a definition along the lines of 'true, justified, belief' we may have to admit *we cannot say much at all about knowledge*.
[https://science-education-research.com/constructivism/knowledge/]



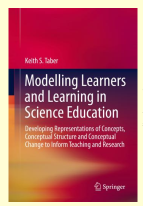
In practice, I know from my own area of research that what we elicit from learners when we ask them about what they have learnt, we find that they have a range of ideas that not only match the canonical account in the curriculum to varying degrees:

but also vary in terms of
• the extent to which they find them convincing;
• the extent to which the ideas are linked into coherent networks and frameworks rather than being little 'islands' of knowledge;
• the extent to which they have alternative accounts of the same phenomena that they can move between;
• the extent to which knowledge is available to conscious deliberation, or is implicit and only provides intuitions and moments of insights.
[https://science-education-research.com/publications/books/student-thinking-and-learning-in-science/]
So learning can involves changes in these characteristics regarding existing knowledge, as well as learning 'new things'.

manifold conceptions

people may hold alternative versions of a concept

(e.g., ‘energy’)



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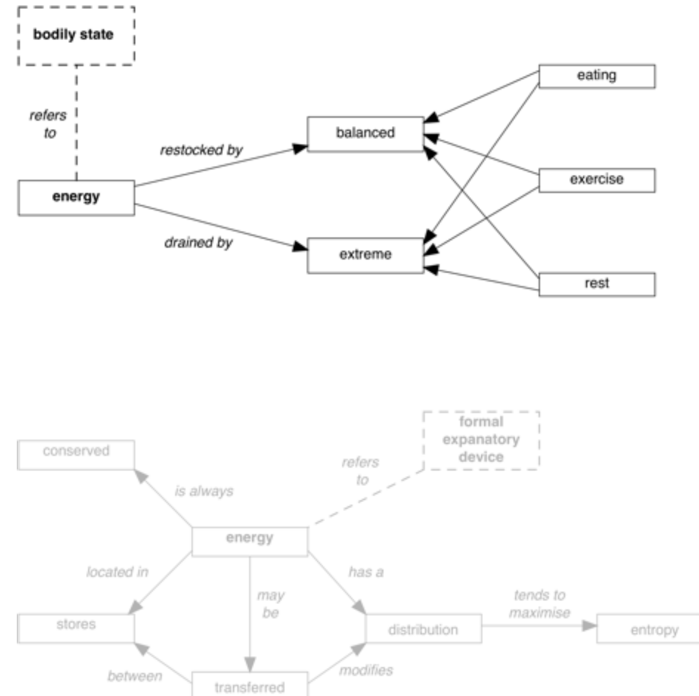

Learning then has to be understood in terms of such matters as sometimes subtle changes in the weightings of different alternatives,

manifold conceptions

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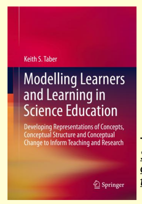

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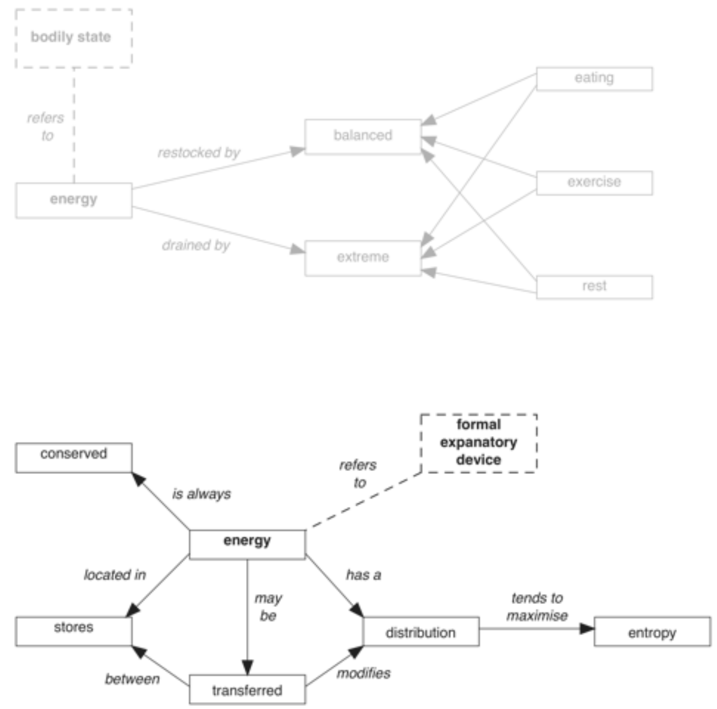
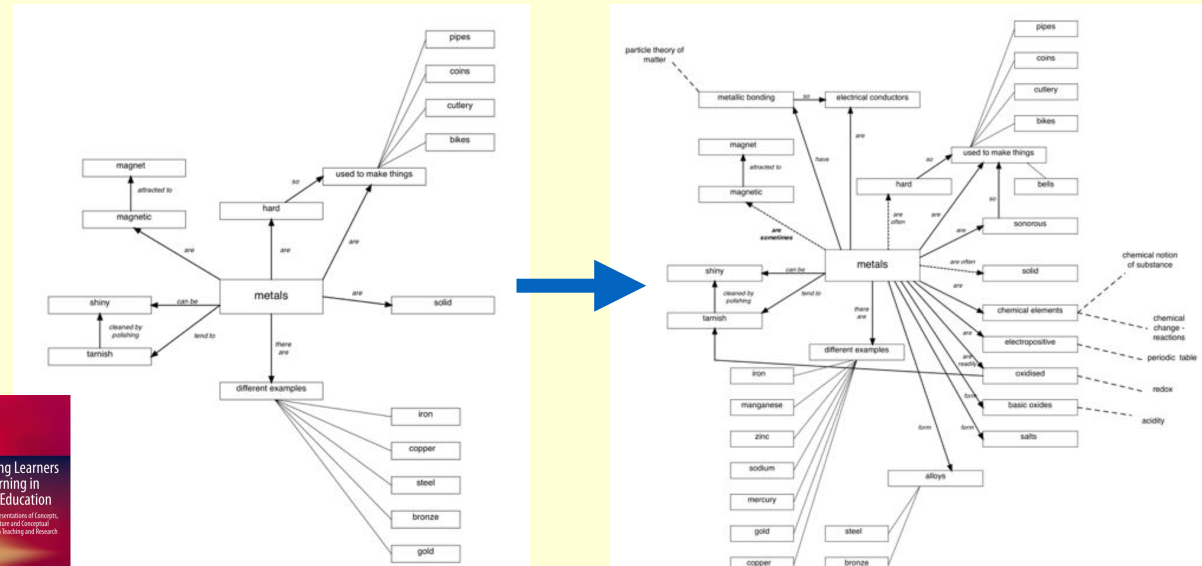
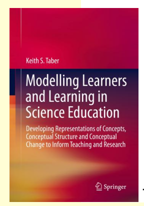


conceptual structure





Taber, K. S. (2013). *Modelling Learners and Learning in Science Education: Developing representations of concepts, conceptual structure and conceptual change to inform teaching and research*. Dordrecht: Springer.

or in shifts in degree of connectivity within knowledge structures,

The core principle…

…of constructivism is very simple

learning is an active process that takes place in the mind of a learner

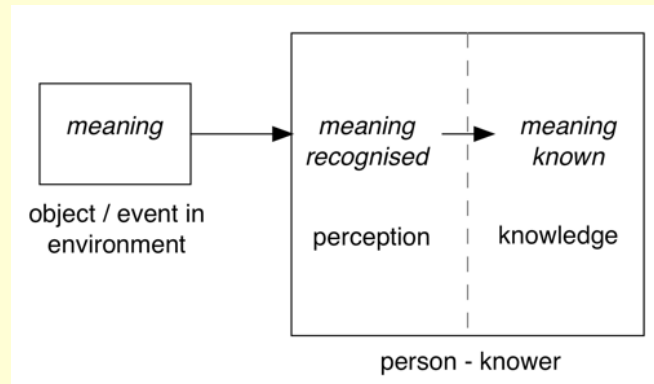
this raises two important questions:

1) an active process that takes place in the mind of a learner rather than what - *what else might people think learning is?*

2) does this mean learning is *not a social* process?

So returning to the question of what else might people think learning is?

Knowledge as something acquired from the environment?

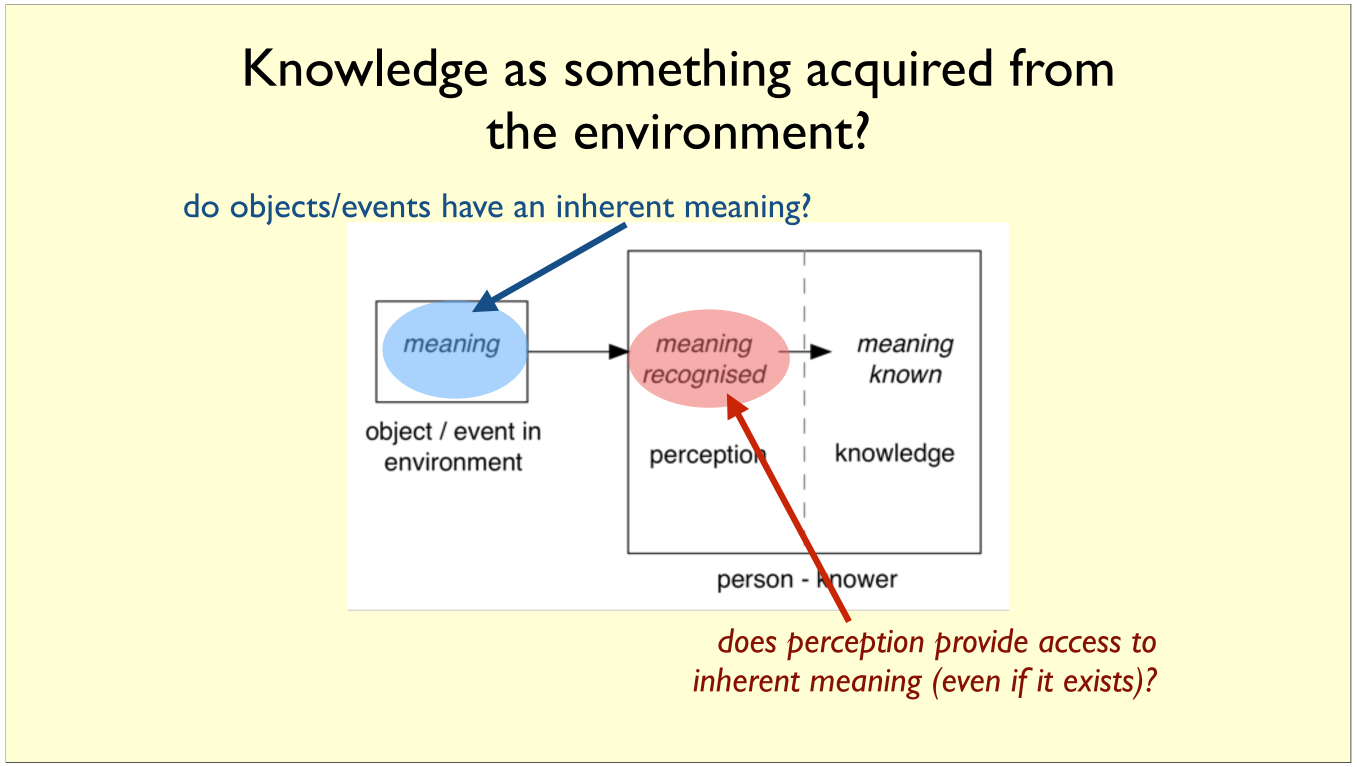


a common *informal* assumption: something that we often take for granted

Taber, K. S. (2011). ***Constructivism as educational theory: Contingency in learning, and optimally guided instruction***. In J. Hassaskhah (Ed.), *Educational Theory* (pp. 39-61). New York: Nova.

There is a widespread informal notion about how we come to knowledge of the world [https://science-education-research.com/publications/chapters/constructivism-as-educational-theory/].

This is, that we use our senses to observe objects or events in our environment, and so are able to recognise the meaning of those objects and events.



There is an ontological assumption there about the nature of the world - it contains things that have inherent meanings for us to recognise.
There is also an assumption that human perception allows us to recognise these meanings.

Knowledge as something acquired from the environment?

do objects/events have an inherent meaning?

We will see some images.

does perception provide access to inherent meaning (even when it exists)?

For each image ask yourself

a) what the image means to you

b) whether that meaning is inherent/intrinsic to the object scene shown (would a visitor from Alpha Centauri also recognise it?)

c) i) how do you 'know' what is being represented?

ii) would you always have known?

iii) if not, when did you acquire this knowledge?

Compare notes with anyone watching this lecture with you.

But we can easily see this is questionable. For one thing, objects in our environment do not generally have an objective meaning that is independent of the observer.
Consider the following images, which some of you may have previewed before the lecture.
[https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See: 'Meaningful images?']

If not, for each image you can ask yourself
a) what the image means to you
b) whether that meaning is inherent/intrinsic to the object or scene shown
c) i) how do you 'know' what is being represented?
ii) would you always have known? Or did you have to learn this?
iii) if the latter, when did you acquire this knowledge?

Ask yourself
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36

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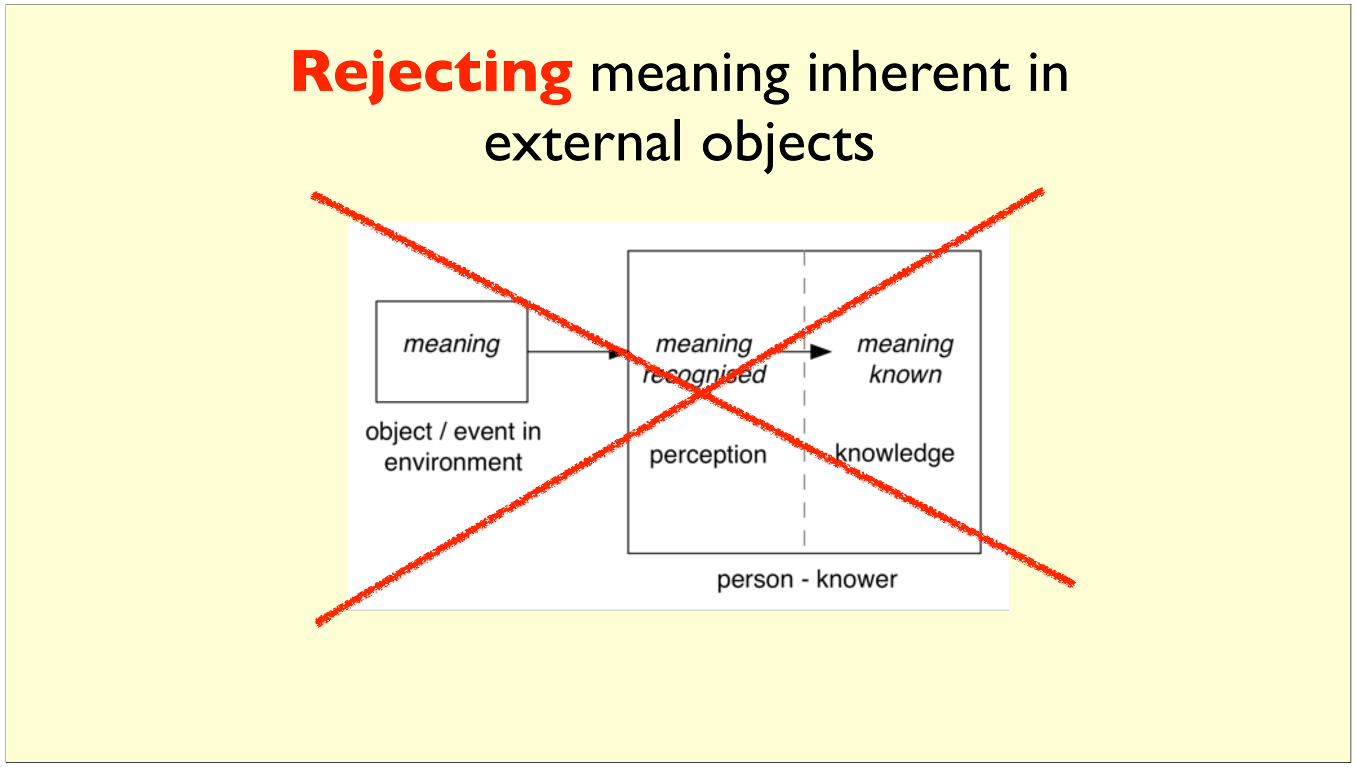
Uluru or Ayers Rock is just a geological feature to some observers, but is a sacred place to others. Drinking tea might just be responding to thirst - or in some contexts may have ceremonial meaning. We know that a handshake has a special meaning, but would an alien recognise this - especially a visiting alien who did not have hands? Should we be worried about the gentleman who seems to be carrying a sword? I guess you did not understand that image as threatening, but quite differently - perhaps as source of pride or patriotism? What could be seen as just a building that is in danger of falling over, may for some be the site of a famous, apocryphal experiment said to have been carried out by Galileo.

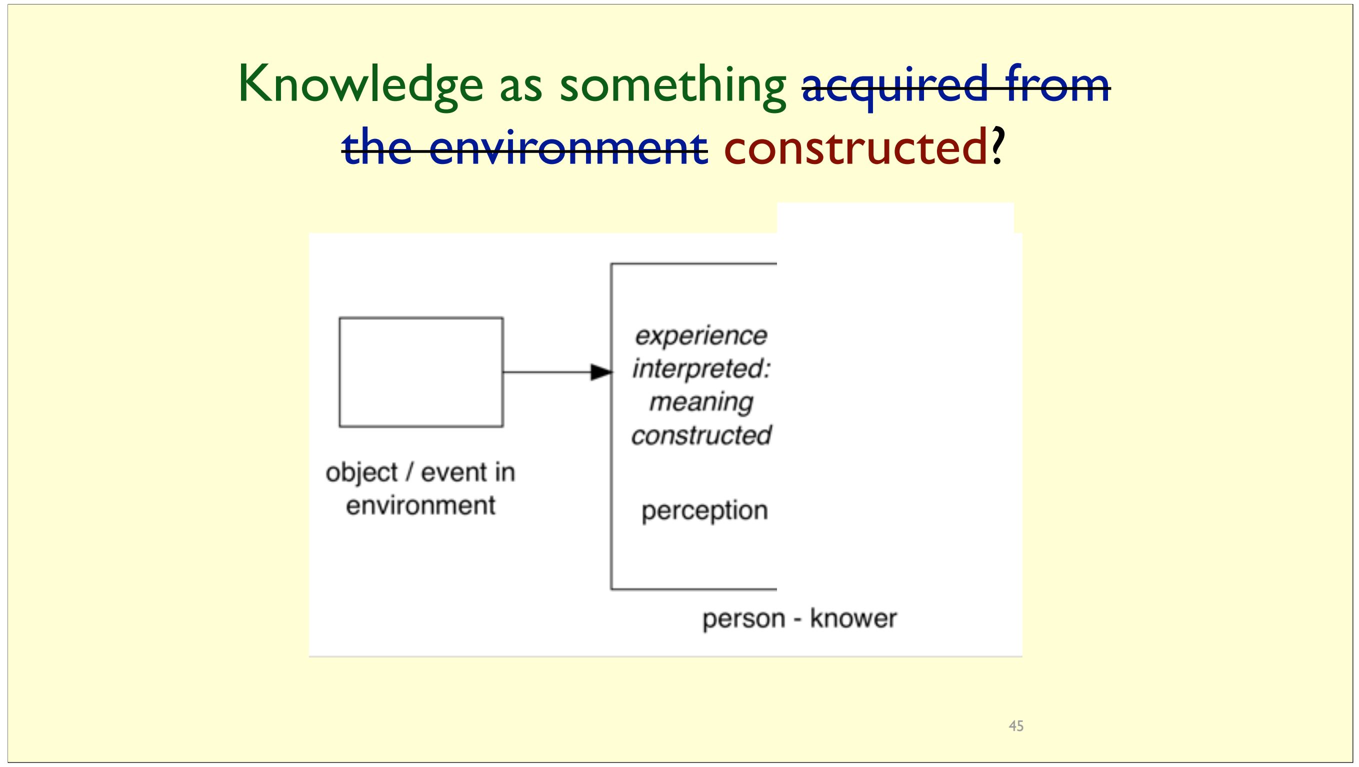
Red roses have a special significance in my cultural context, but perhaps not in all other parts of the world. And why do those strange people throw their hats in the air - what sense would a visitor from outer space make of that?

I particularly like the image of the eclipse. Oh, there is no image of an eclipse shown there! But I suspect you know exactly which image I mean. I very strongly interpret the scene as an eclipse, despite there being no eclipse actually shown.

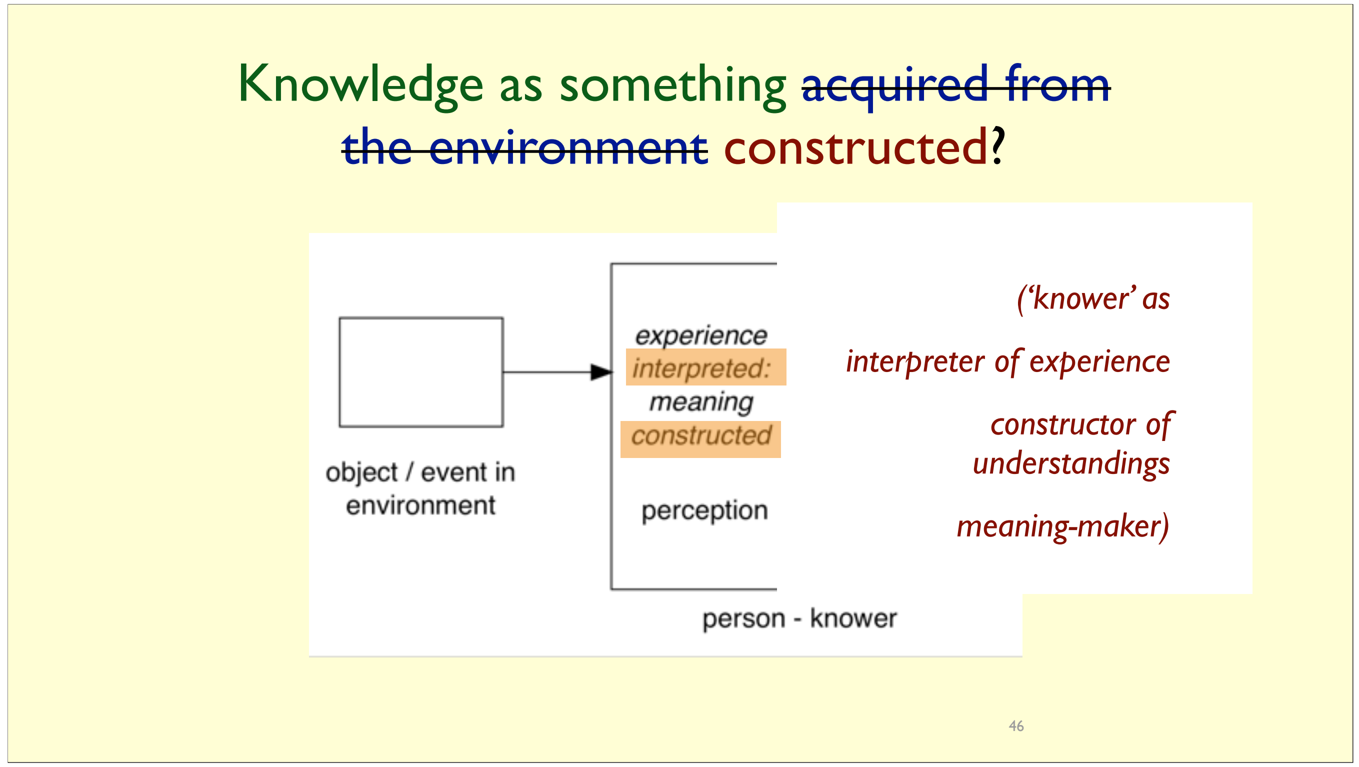
Even when an object is designed and built for a purpose, there is nothing to stop a person deciding it has a different meaning to them.



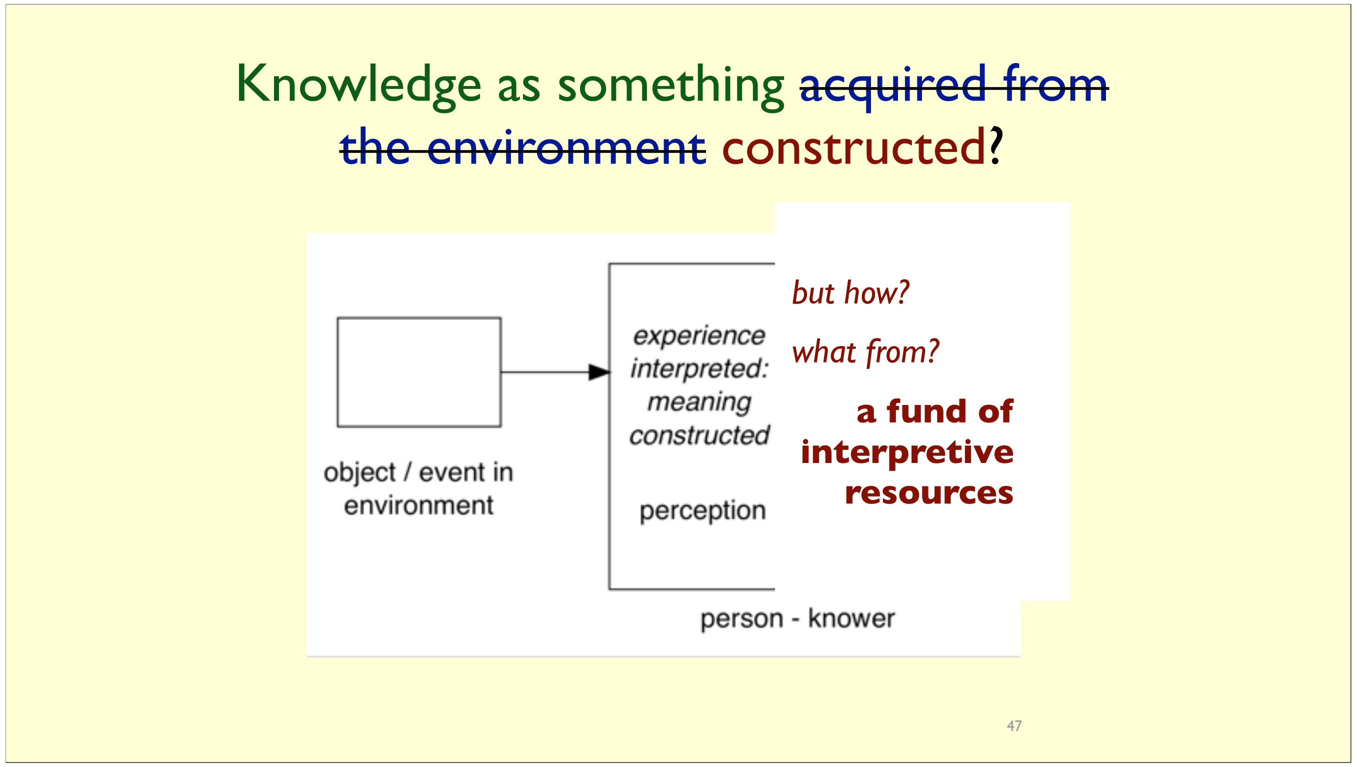
So, I reject the idea that we can recognise inherent meaning.



Rather, we have to interpret the information from our senses.

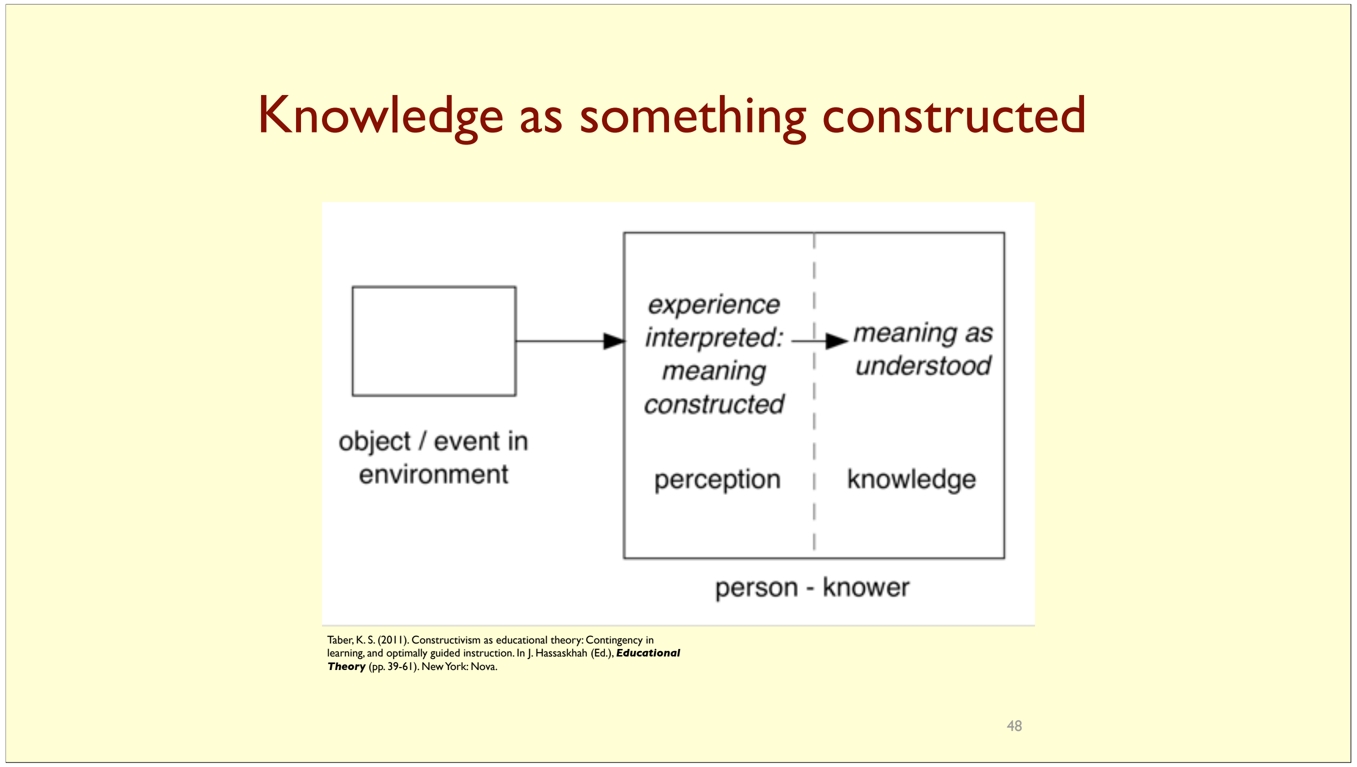


And to interpret, we must have a fund of resources, ideas, images, experiences, to help us make sense.



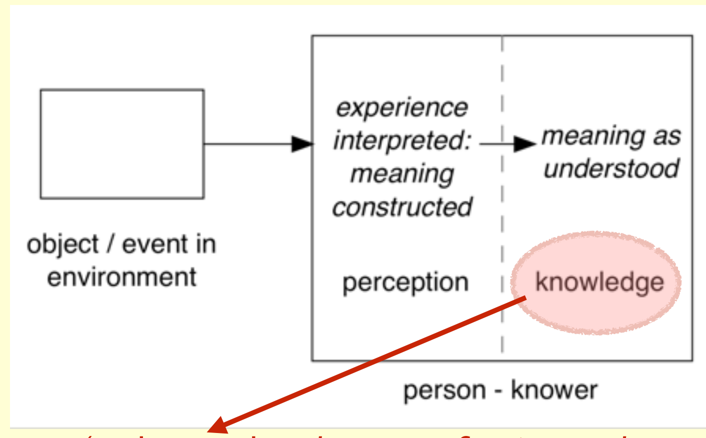
So, we construct meaning in perception. Perception is an active process of sense making.

Perception requires prior learning. In a sense when we perceive an object or scene rather than just a lot of shape and colour, we are using representations of prior experience, so in a sense we use memory to perceive.



And our knowledge is the outcome of that active process of making sense [https://science-education-research.com/publications/chapters/constructivism-as-educational-theory/].

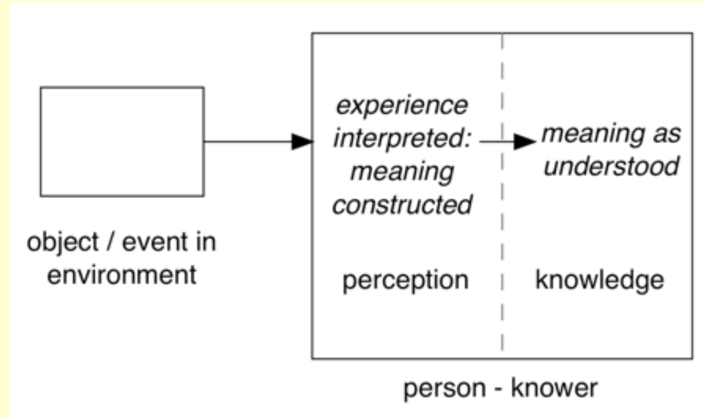
Knowledge as something constructed



(understood as *the range of notions under current consideration as possibly reflecting some aspect of how the world is*)

Bearing in mind that by knowledge we mean something more fuzzy and fluid than justified, true, belief.

Knowledge as something constructed

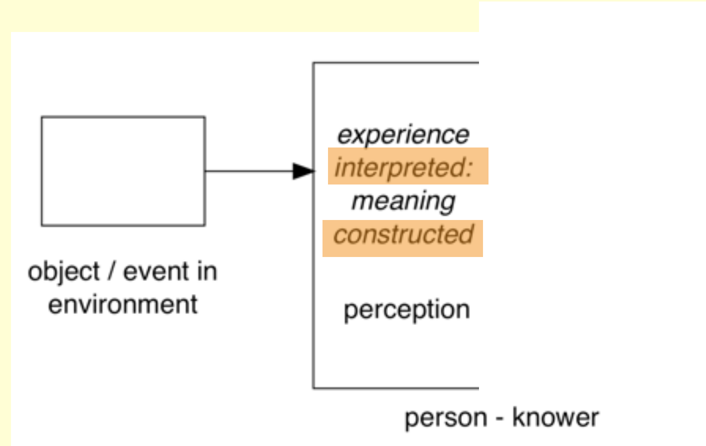


What is the apparatus used for constructing?

Where does this fund of resources originate?

Which raises new questions about the means by which interpretation take places and the origins of the fund of resources used.

Knowledge as something ~~acquired from the environment~~ constructed?



('knower' as

- *interpreter of experience*
- *constructor of understandings*
- *meaning-maker)*

('knower' as the curator of a constellation of notions under consideration as possibly reflecting some aspect of how the world!)

But this perspective is quite different from the naive and commonplace way of thinking about how we perceive things around us.
We perceive in order to learn, but perception itself depends upon prior learning. We build up knowledge of the world, but only by using existing knowledge to make sense of what we are seeing and hearing.

The learning paradox

A man cannot search either for what he knows or for what he does not know.

He cannot search for what he knows - since he knows it, there is no need to search -

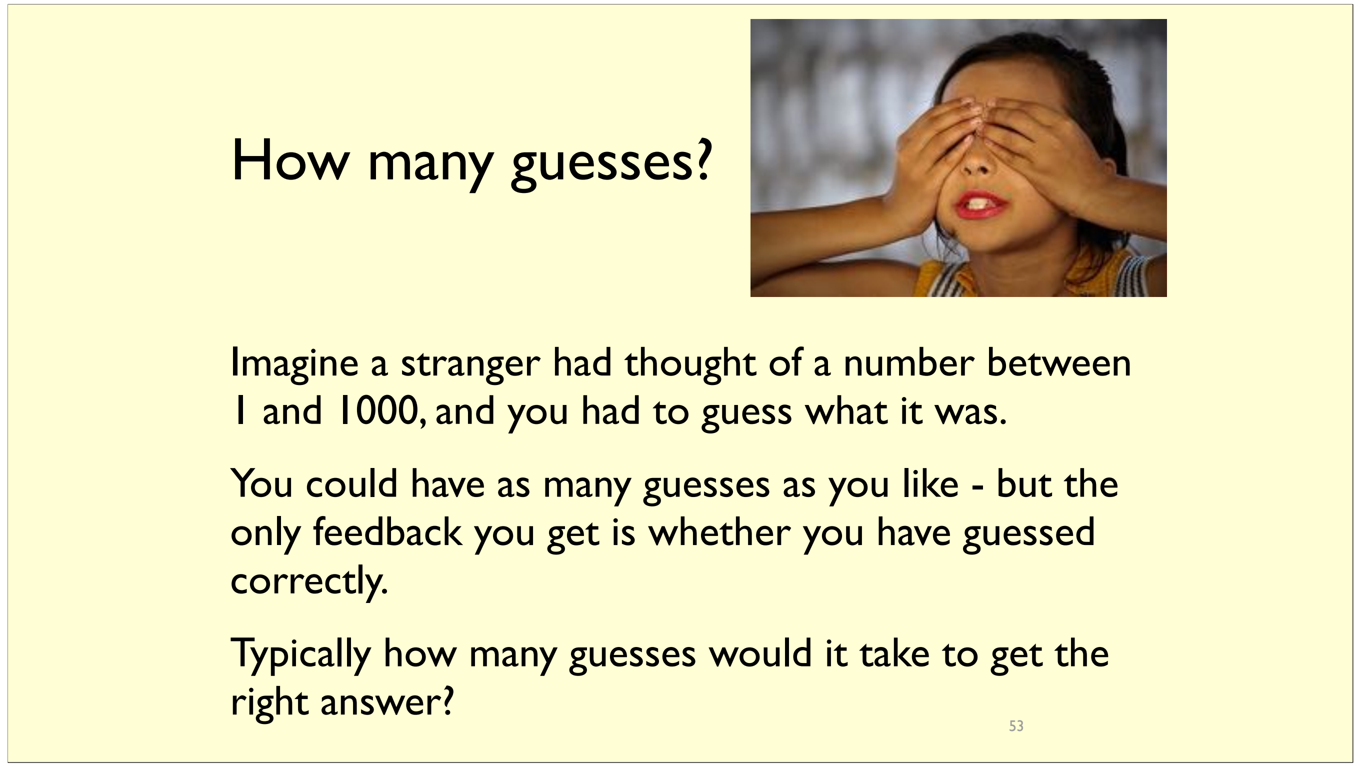
nor for what he does not know, for he does not know what to look for.

[Socrates]

This also raises the question sometimes known as the learning paradox, which was hinted at above. How can we come to knowledge - because if we do not already have knowledge, how will we recognise it when we come across it?

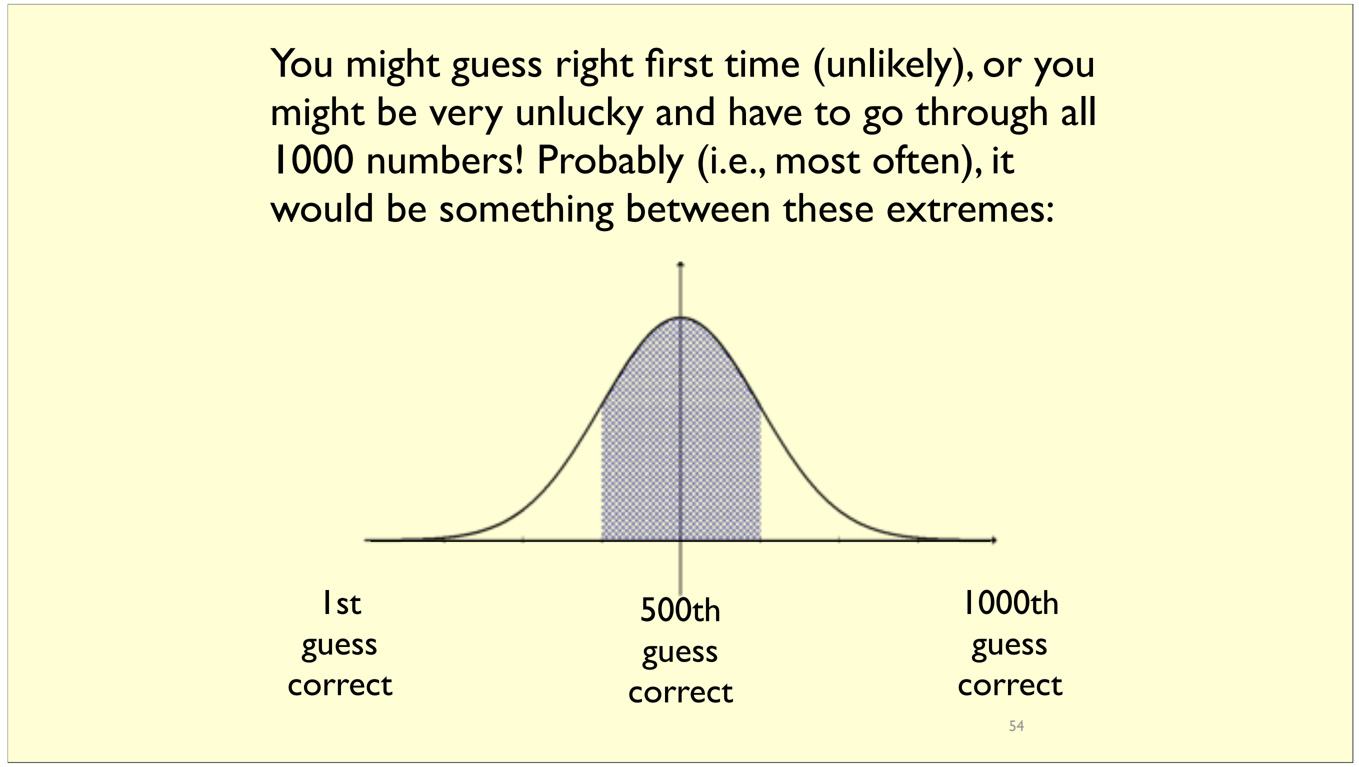
We could always just guess - but that might be a rather poor approach to epistemology.

We sometimes talk about learning by trial and error, but if this means we guess; and if we are wrong, just guess again; and keep on setting up more trials, till we eventually guess successfully; this could be very inefficient - not to say frustrating and tedious.



You may have looked at my questions about guessing. [https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See 'Thinking about two guessing games…']

Imagine a stranger had thought of a number between 1 and 1000, and you had to guess what it was.
You could have as many guesses as you like - but the only feedback you are given is whether you have guessed correctly.
Typically how many guesses would it take to get the right answer?



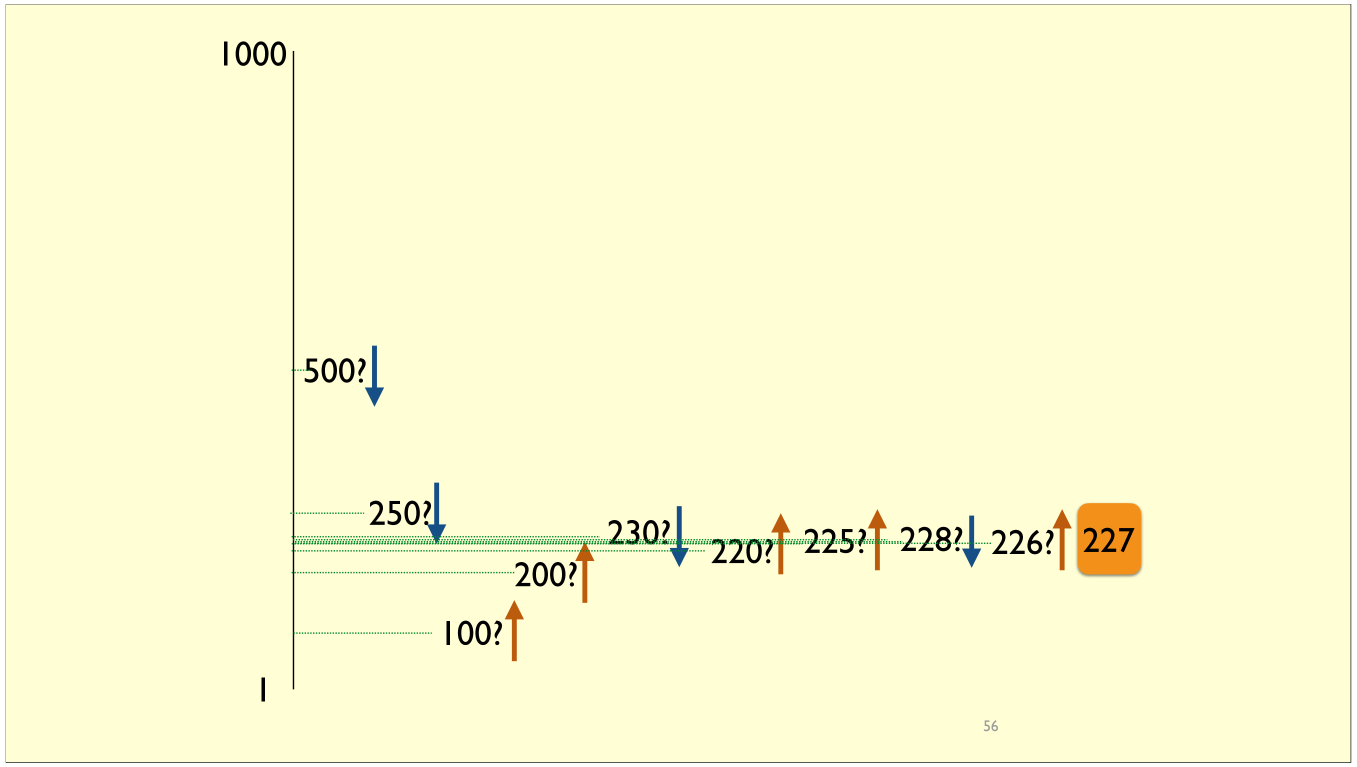
You might guess right first time (unlikely), or you might be very unlucky and have to go through all 1000 numbers!

Probably (i.e., most often), it would take several hundred guesses.

Guessing with feedback

Now consider how much easier the task becomes if you get told whether your answer is too large or too small - you can make an initial guess, but then narrow down the possible answers…

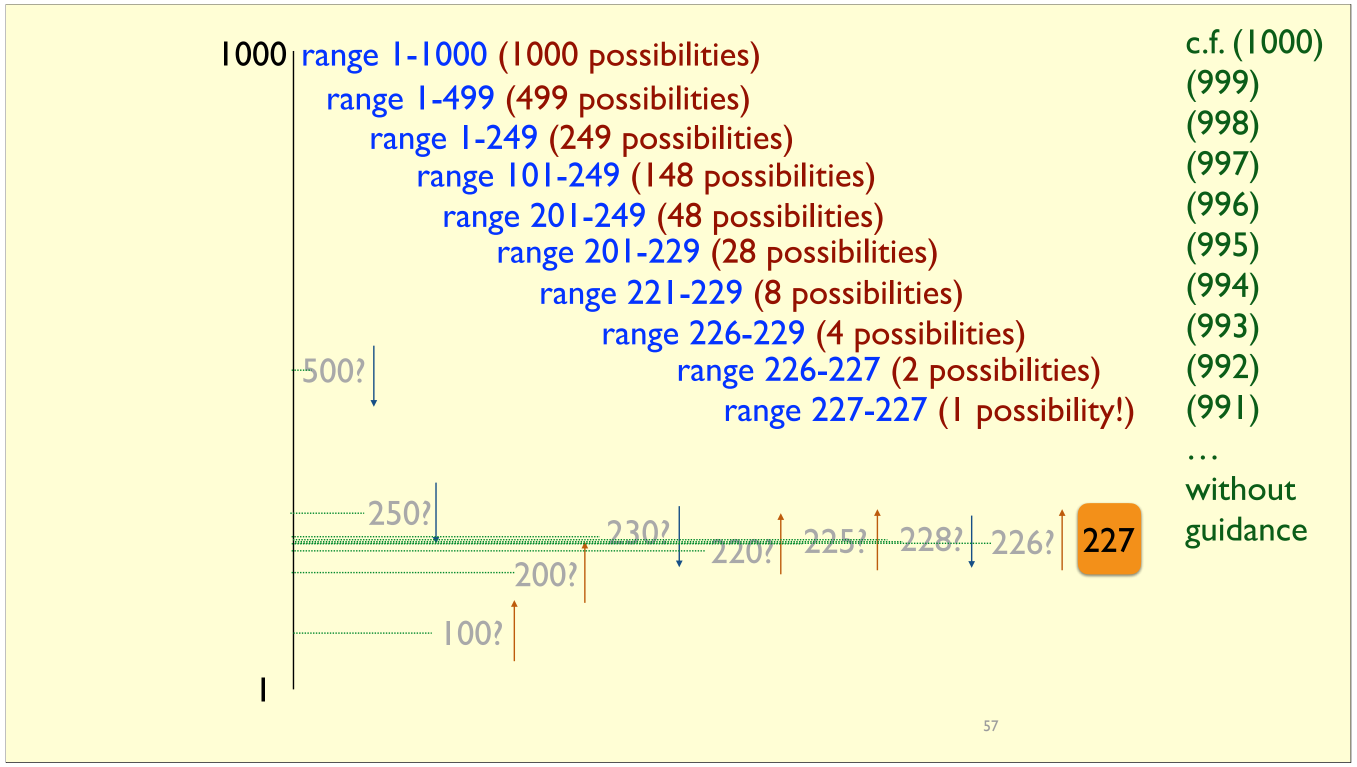
But what if we had some feedback not just about being wrong, but about the way in which we were wrong - what if we were told which direction we needed to go next?



Here is an example of the same guessing game, amended to get feedback on which direction we need to go.

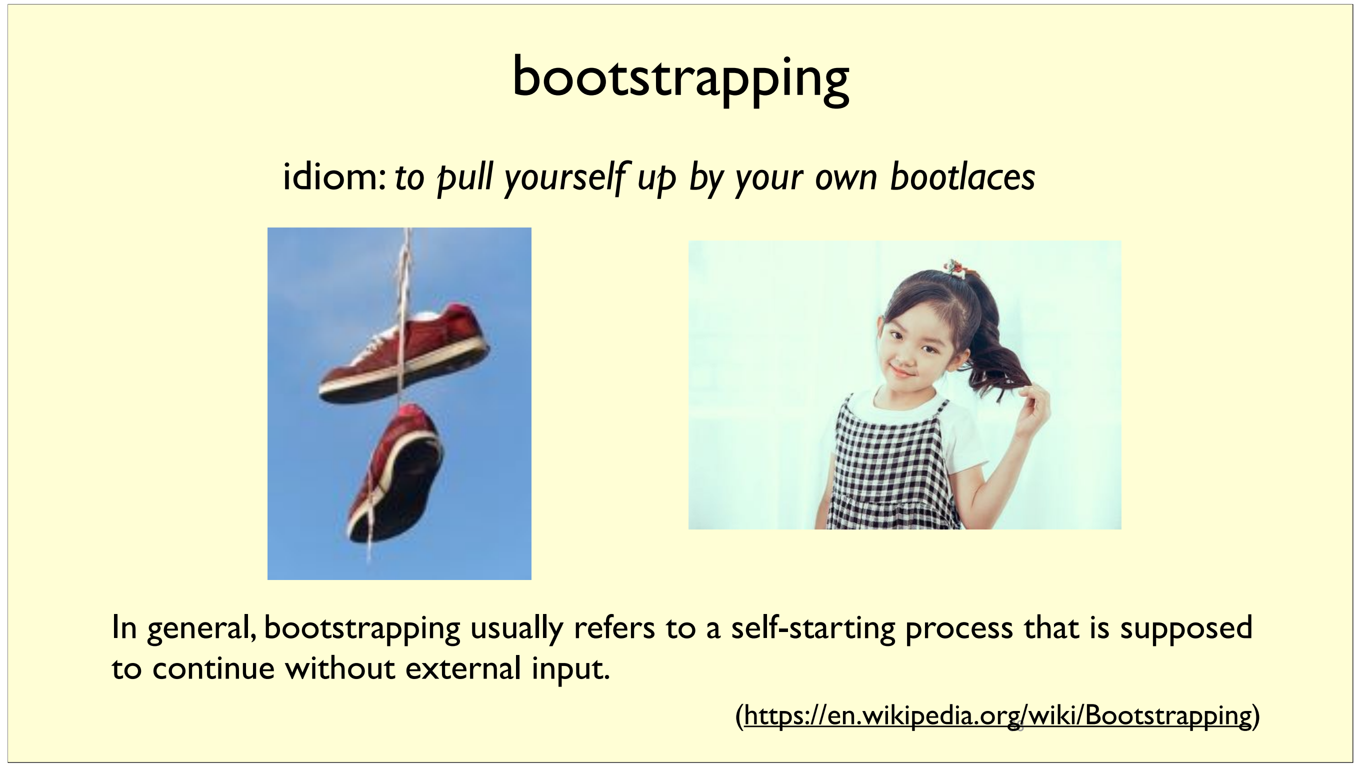
I first guess at 500, and am told the number I am looking for is smaller.

By making sensible guesses I can soon home in on the target number.



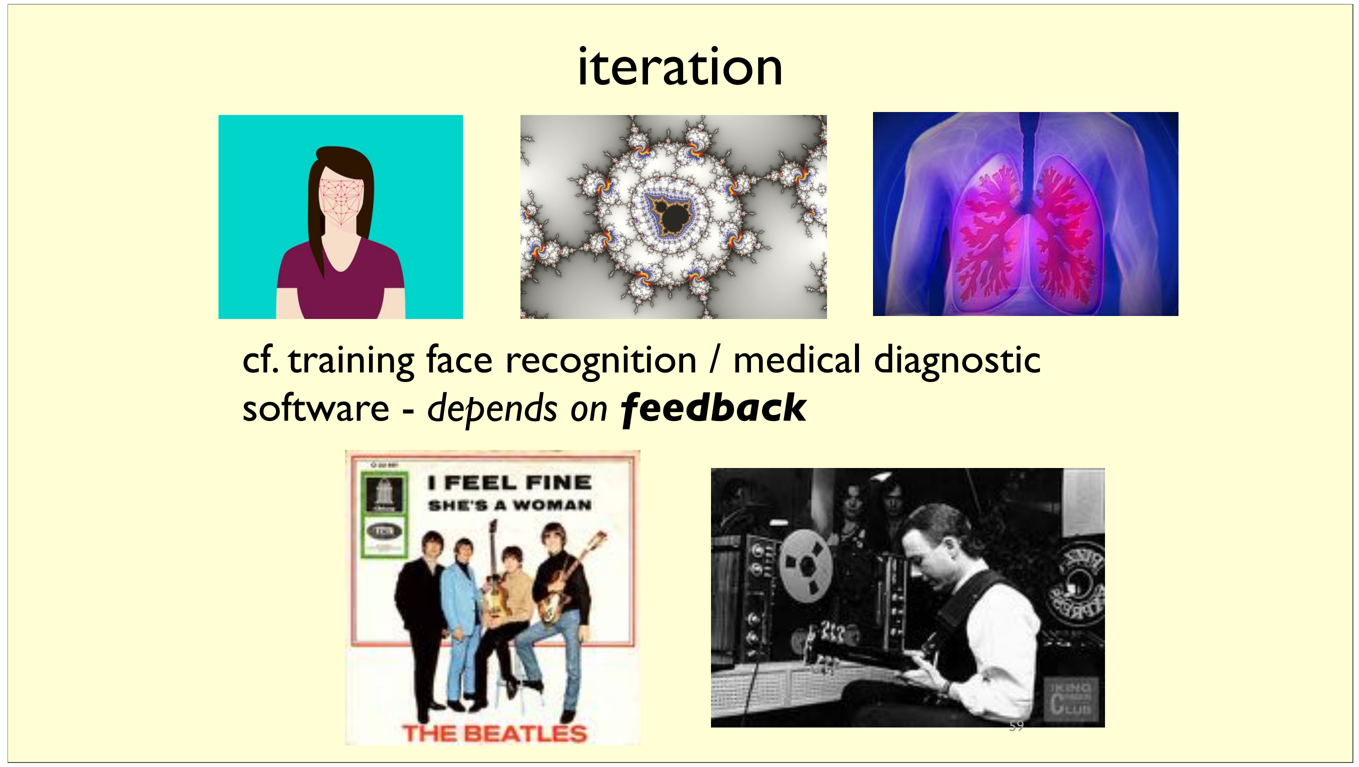
As you see, many fewer guesses should be needed, as very quickly the number of untested options which might be the answer gets quite small.

Whereas, without the guidance, we only eliminate one potential answer per guess.



This is relevant to learning because human cognition allows us to use a kind of bootstrapping process.

This is a little like the (apocryphal) person who got stuck in a swamp, but was able to pull themselves out by pulling up on their own hair.



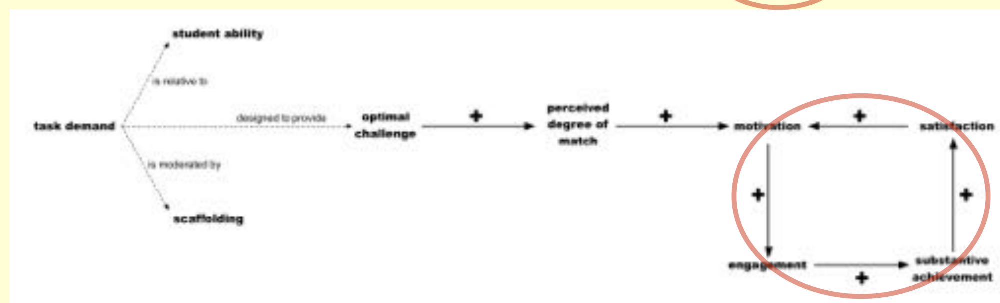
It relies on iteration, the process used in producing fractal designs from simple formulae.

Machines have been taught to learn skills by training them to guess and then giving them feedback on their performance

Given enough training machines can learn to recognise faces and to help in medical diagnosis - such as checking scans, In some cases the machines are thought to be more accurate than humans, and they are much quicker.
Feedback is also a taken advantage of in music. Some of you may be old enough to remember this successful beat combo, who started one of their 45s with some feedback [The Beatles, 'I Feel Fine'] - very novel at the time.

Some musicians [such as Robert Fripp, shown here] have even developed ways of using iteration as the basis for composing music with loops that build up over time.

example of feedback cycle



Taber, K. S. (2015). Affect and Meeting the Needs of the Gifted Chemistry Learner: Providing Intellectual Challenge to Engage Students in Enjoyable Learning. In M. Kahveci & M. Orgill (Eds.), *Affective Dimensions in Chemistry Education* (pp. 133-158): Springer Berlin Heidelberg.

A '+' (or '-') symbol shows the direct of effect of one variable on the next…

…so, for example, here (+)

increased student motivation is likely to end to increased student engagement

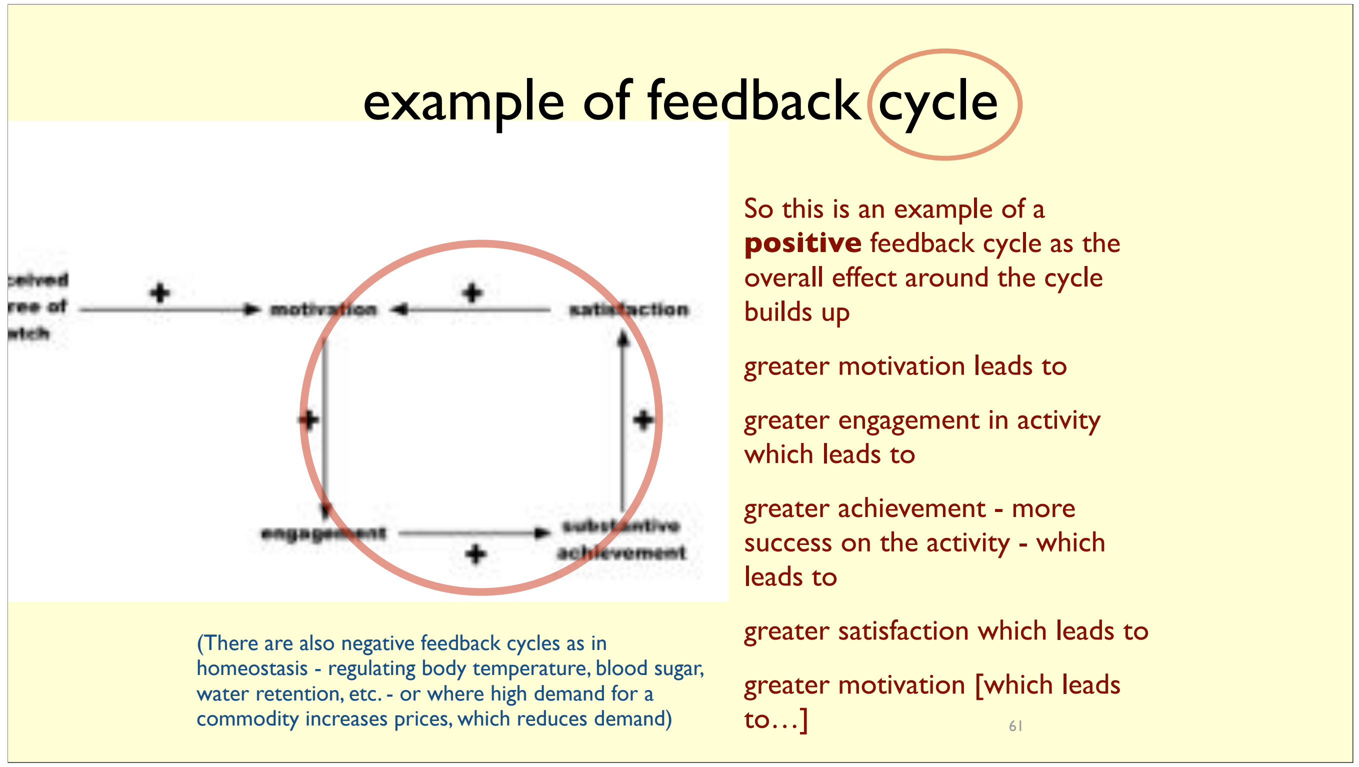
and

decreased student motivation is likely to lead to decreased student engagement

Feedback cycles are very important in environmental and biological systems.

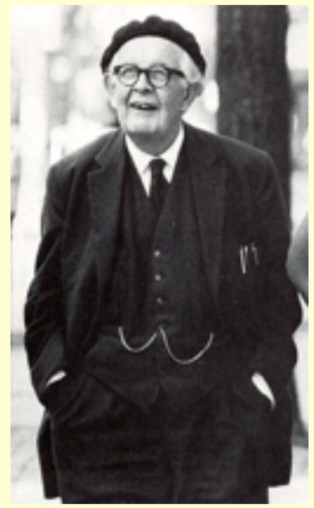
Here is an example from education, where ensuring a match between task difficulty and student capability is important for setting up a virtuous circle of increasing motivation.

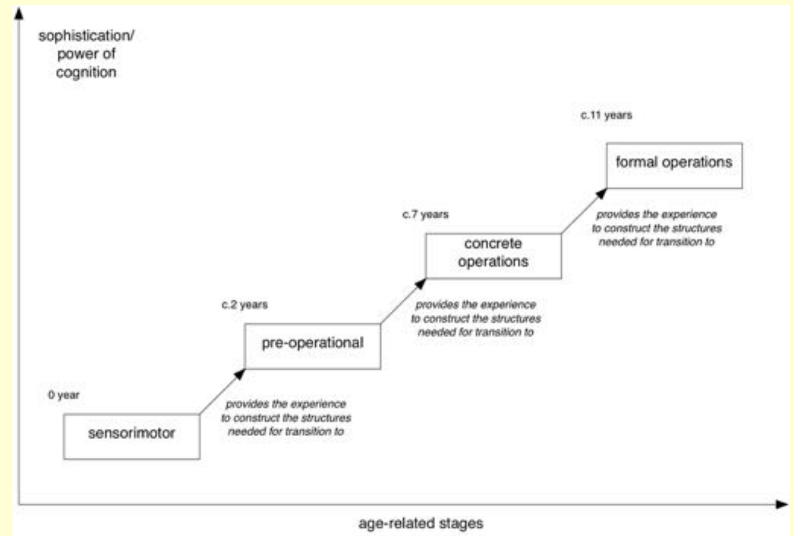
[https://science-education-research.com/publications/chapters/providing-intellectual-challenge-to-engage-students-in-enjoyable-learning/]



So this is an example of a positive feedback cycle as the overall effect around the cycle builds up
greater motivation leads to
greater engagement in activity which leads to
greater achievement - more success on the activity - which leads to
greater satisfaction which leads to
greater motivation
and so on.

Our starting point will be to focus on the learner, and treat everything around the learner a part of their environment Jean Piaget

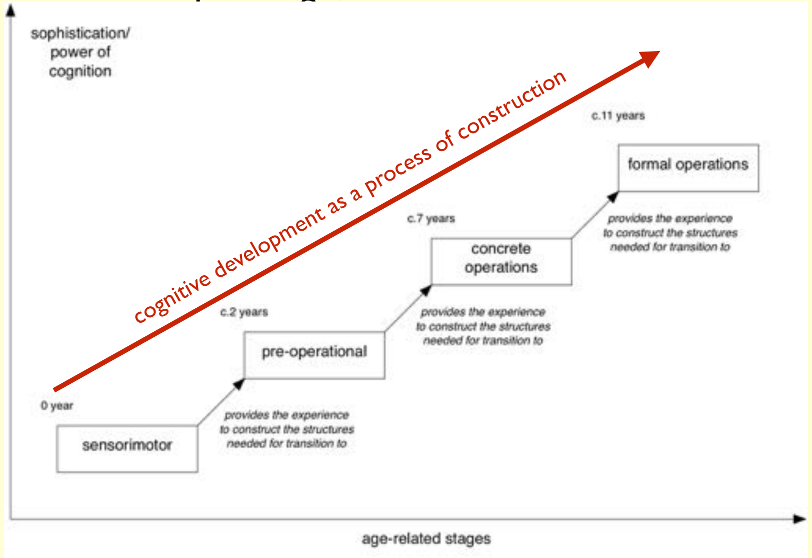




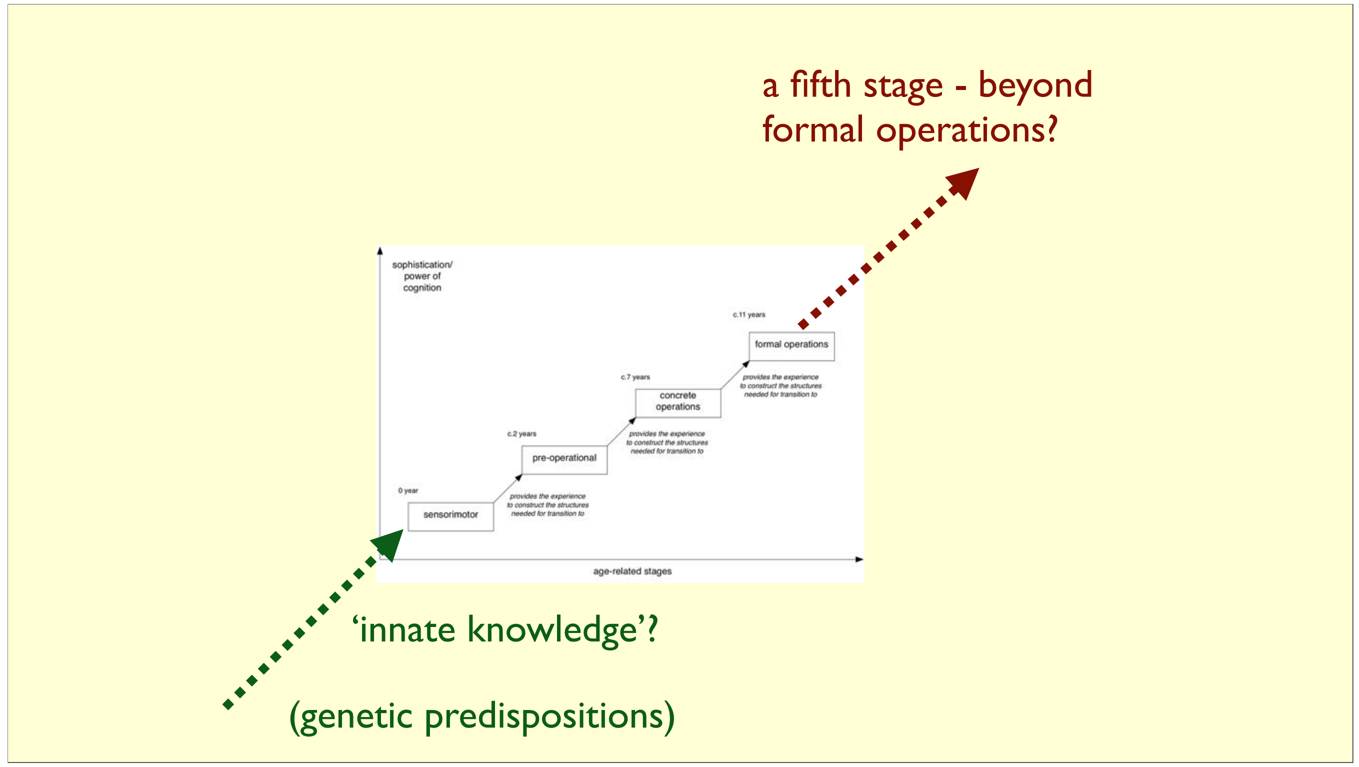
And iteration and feedback were also key aspects of Piaget's model of conceptual development,

Our starting point will be to focus on the learner, and treat everything around the learner as a part of their environment

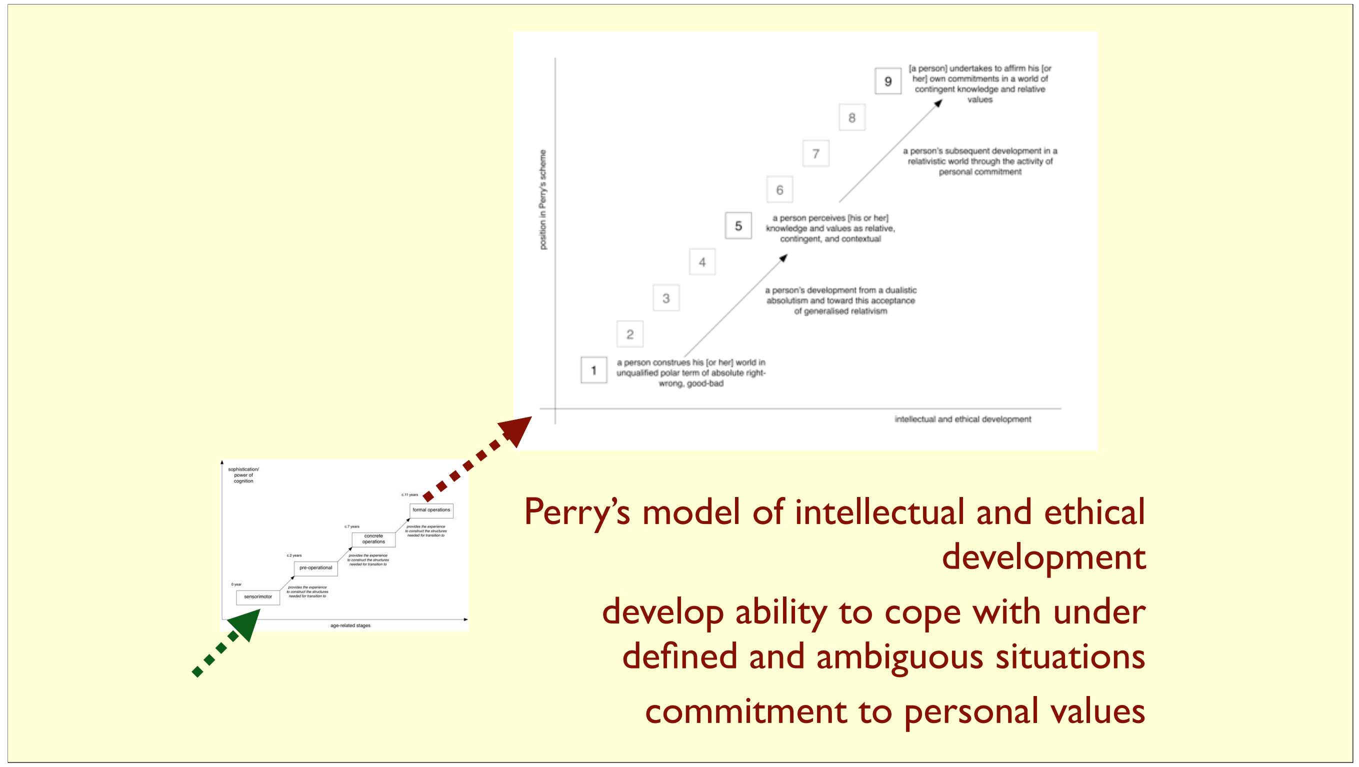
Jean Piaget



In Piaget's system a child has limited cognitive capacity, but uses this to engage in action on the environment, and by observing the effects of that action slowly develops greater capability. The child effectively, metaphorically at least, pulls itself up by its own bootlaces.



Indeed some theorists have argued that Piaget's model needs to be extended as adults need post-formal thinking - thinking that can engage with partial and ambiguous data sets, and the application of a system of values that can be used to guide action when the information available from the environment underdetermines decision-making.

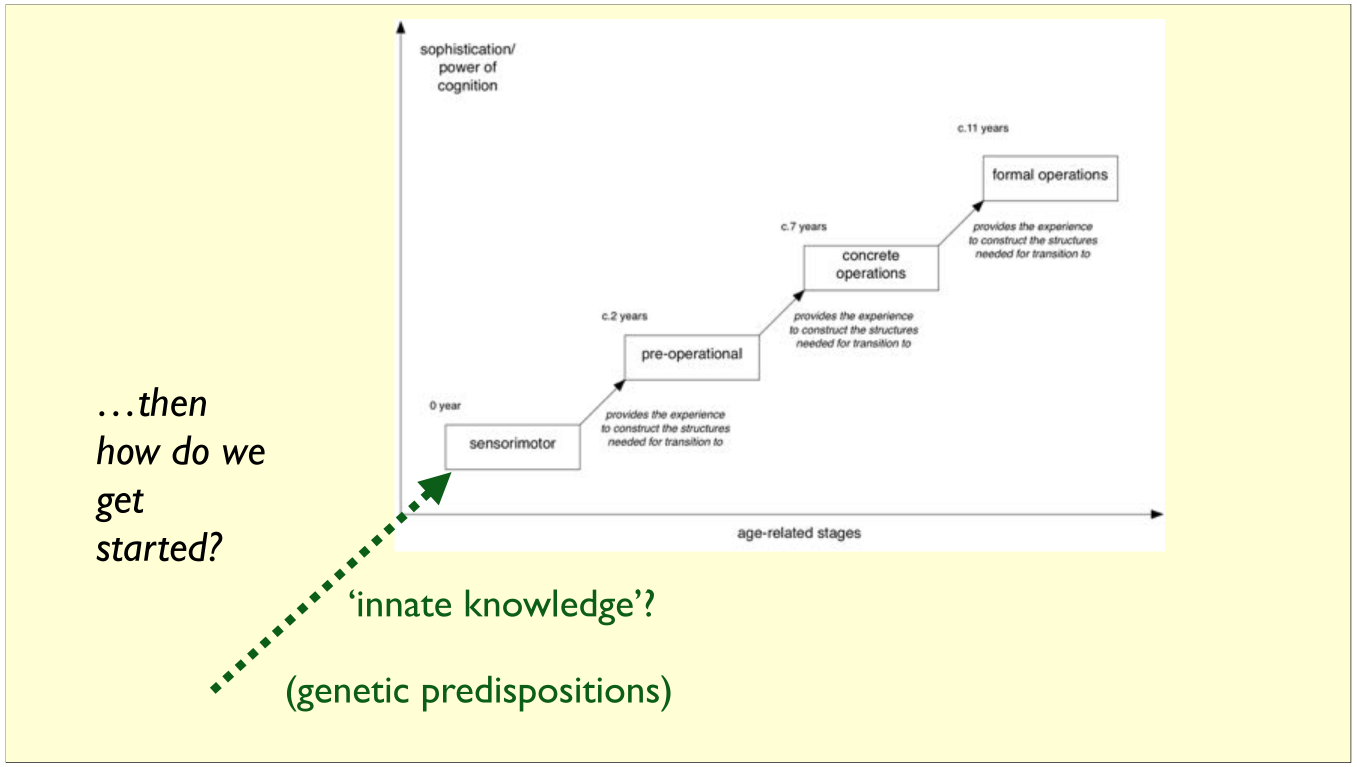


As, for example, in Perry's description of intellectual and ethical development in young adults. [https://science-education-research.com/publications/chapters/developing-intellectual-sophistication-and-scientific-thinking/]

If we construct knowledge…

…then how do we get started?

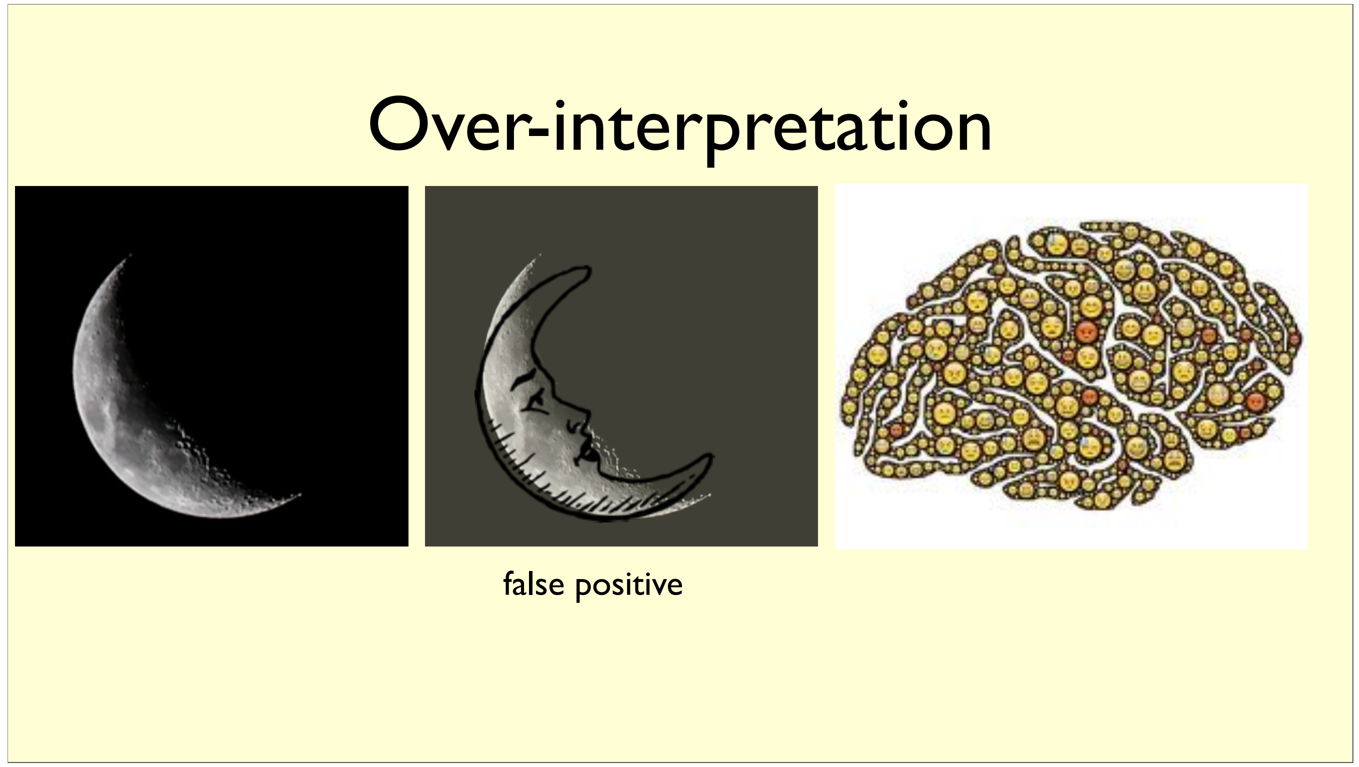
But this leaves a thorny question
if perception relies on a kind of remembering of past learning
if we use prior learning to understand the world so we can learn more - how does this process get started?



It requires us to assume that babies are born with a form of innate knowledge of the world they will live in.
That they have in a sense already been seeded with some starter knowledge.
- which perhaps sounds a bit like magic.

Yet there is plenty of evidence that babies are born at least with some predispositions to understand the world in particular ways.
So, from soon after birth babies can recognise faces - and we all seem to be equipped with a pattern recognition apparatus that makes it easy to see faces even in simple representations such as emoticons.
Babies also show reluctance to cross a visual cliff - that is when presented with the illusion of lack of support.
And babies have been shown to show surprise very young when they see some physically impossible scenes - such as an object placed under a cushion, which is no longer there when the cushion is lifted.

They seem to be born knowing the universe should work in certain ways.

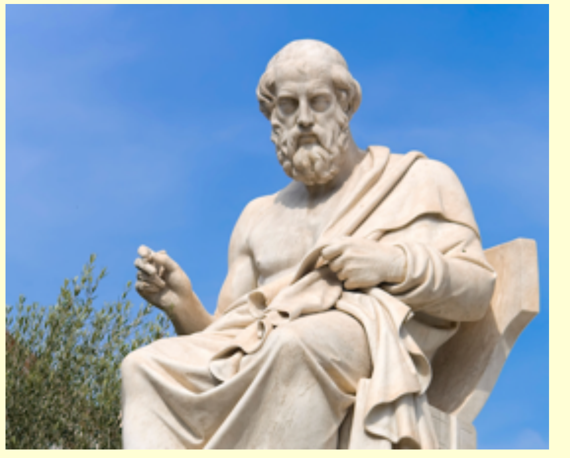


In relation to faces, we seem to be prone to see them everywhere - this is presumably such an important skill in the new born that the brain has a predisposition to over-interpret in this regard. Perhaps false positives (seeing faces where there are none) is less of a problem than false negatives, a young baby not being able to recognise the faces of family.

innate knowledge?

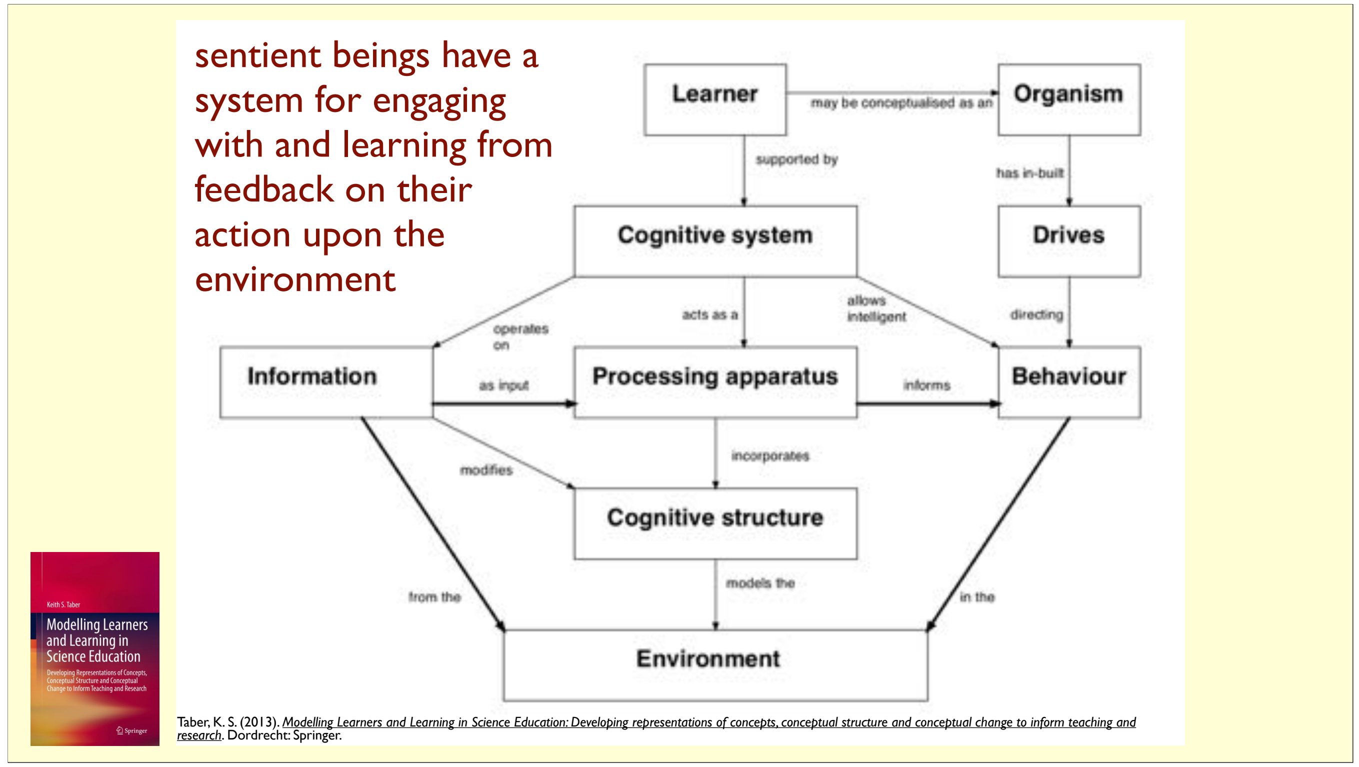
where could that come from?

https://thegallerist.art/reincarnation-and-plato/ (Syamarani dasi)

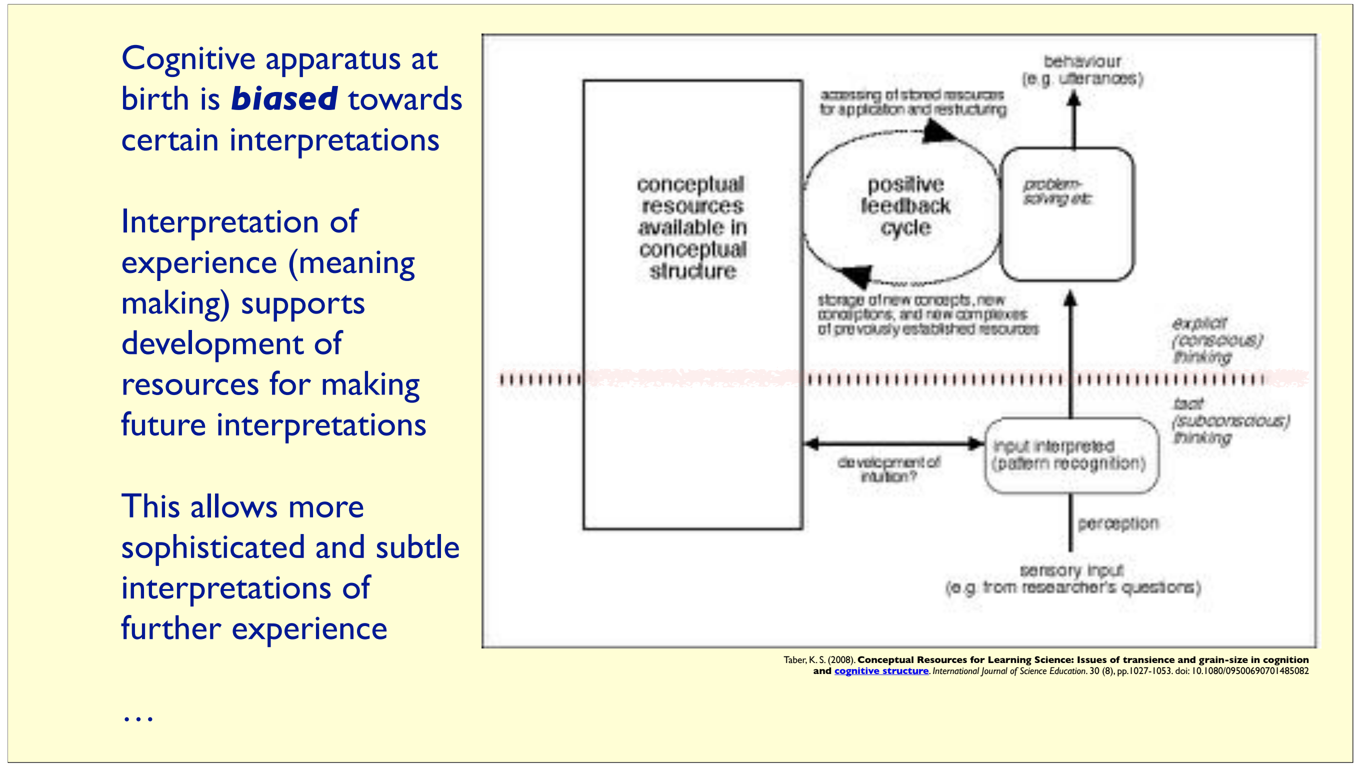


Now, one explanation for this innate knowledge, suggested by Plato for example, is that our immortal souls have knowledge of the basic forms and recognise these in the imperfect copies we find in the real world - in this explanation our souls retain this knowledge as they are reincarnated into new bodies.

Here is a quick representation of an alternative account which assumes that a process of iteration informed by feedback has been operating long before a human is born, as genes are selected to match the nature of the world.



So, a baby is born with the potential to develop into a complex system for engaging with its environment, observing the outcomes of that action, and learning from it.
[https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/]



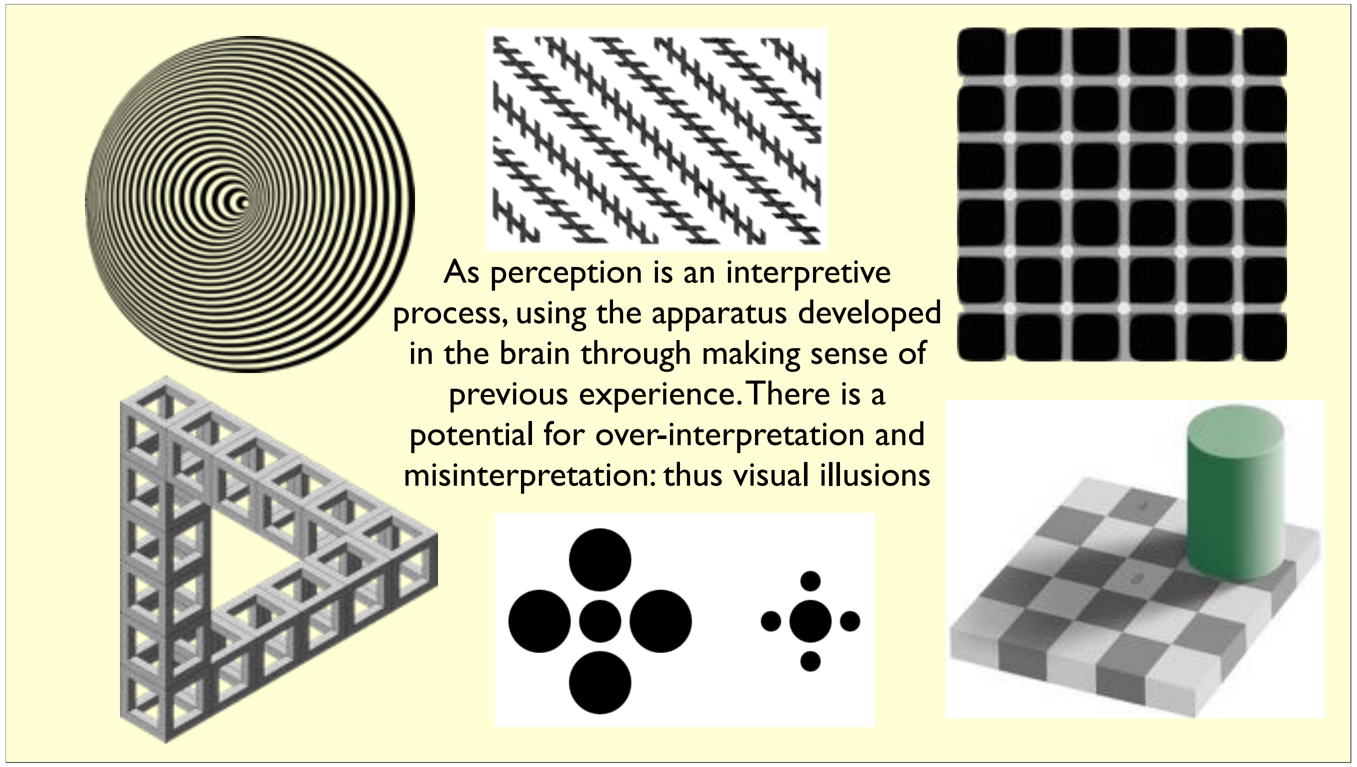
This starts-off the process of developing a fund of interpretive resources based on experiences.

Although some of this may be consciously observed or even controlled, a good deal goes on below the level of conscious awareness [https://science-education-research.com/publications/articles/conceptual-resources-for-learning-science/].

Much of our knowledge is implicit, and supports intuitions. Patterns in experiences in the world are abstracted as implicit knowledge which leads to us having expectations about future experience.

And so to surprises and revisions of knowledge when expectations are confounded.

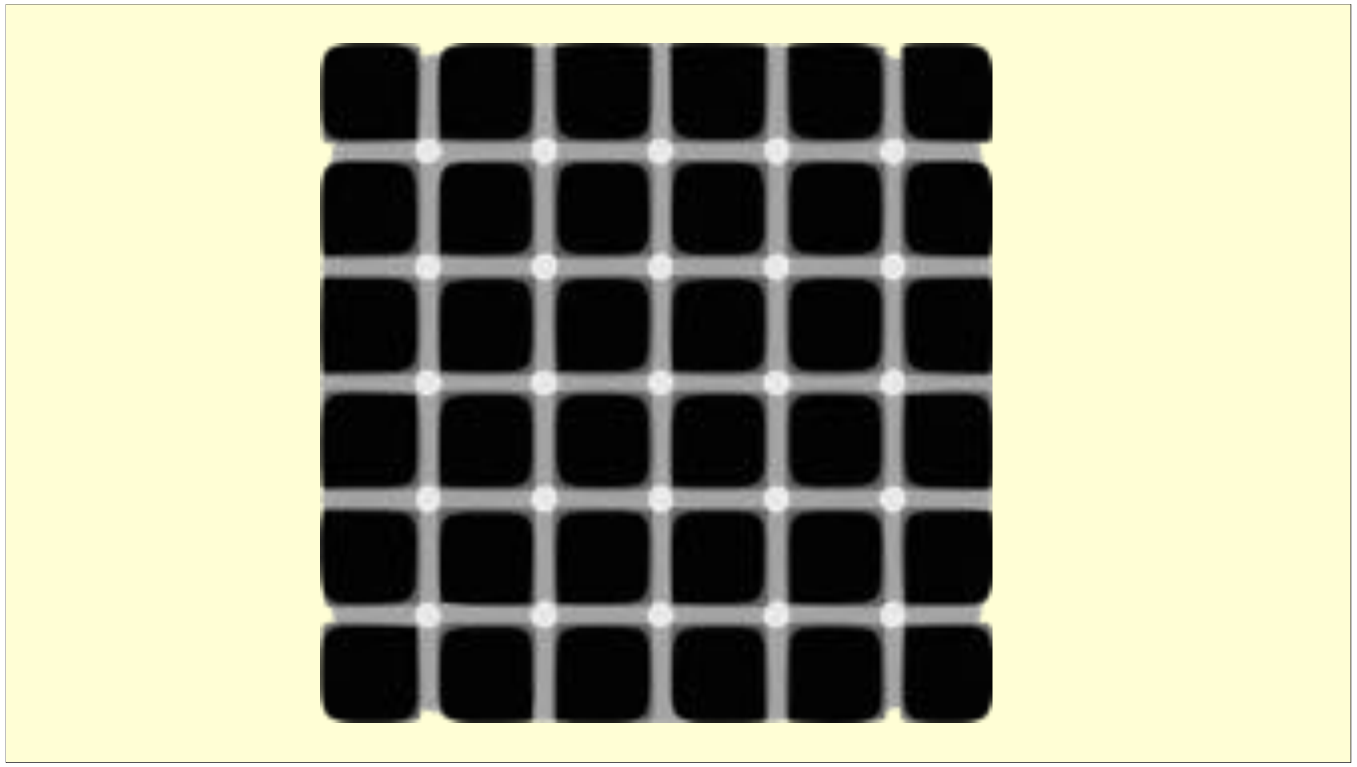
That is, intuition is no more mysterious in nature than your email application identifying junk messages - it is reflecting past experiences that have become built into the processing of the system.



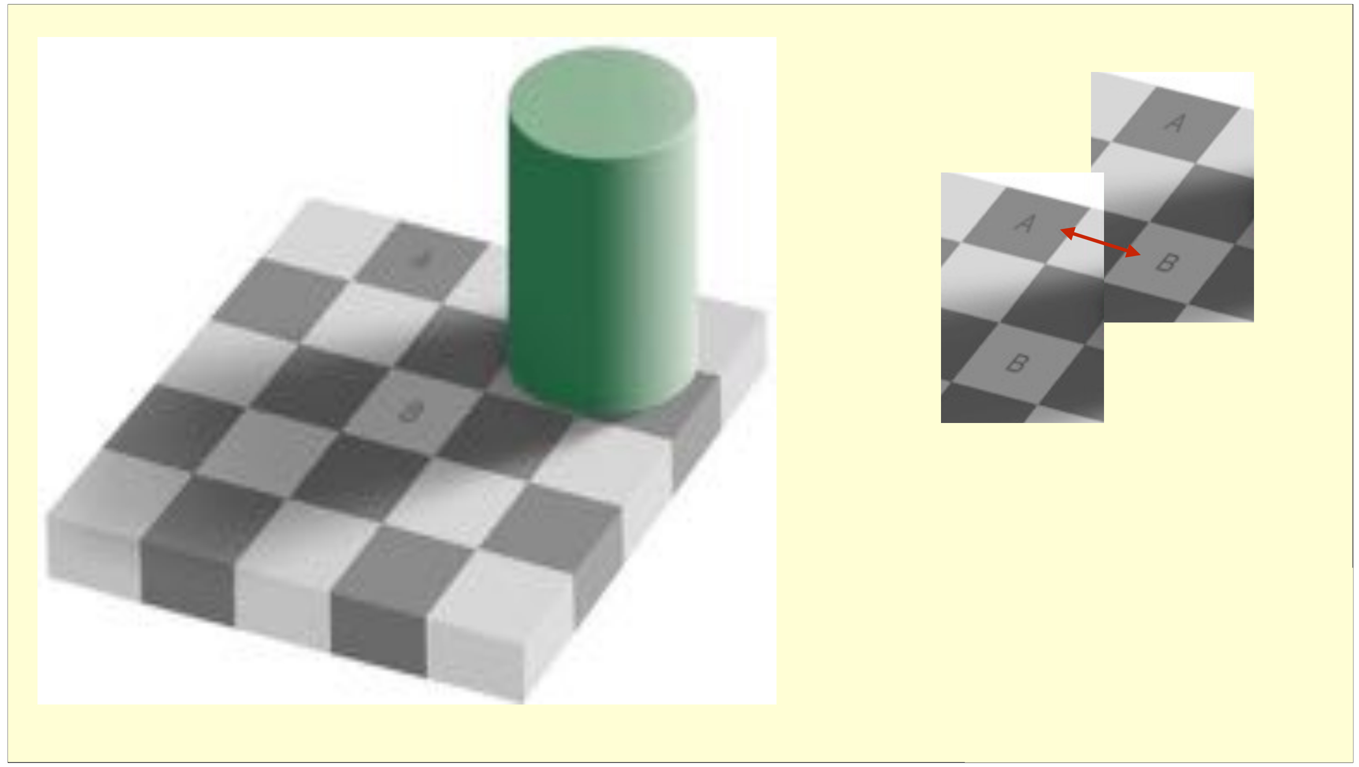
Of course, the system is not perfect. So, it may over-interpret. We see this in visual illusions where our brains seem to be telling us we are seeing one thing, when we know it cannot be the case. The expectations we have developed about the world have become built into perception itself. We do not see a mass of shapes and colours, but see a bus, or a friend, or a crested partridge, or a field hockey match. The interpretation is nearly always complete before the sensory information reaches consciousness. The information has been filtered, and the most important bits selected and interpreted, before we have any conscious awareness.

So we may find we are seeing a three dimensional shape when we know we are looking at something flat. [https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See 'What do you see?']
Even though we tell ourselves it is flat - we still see depth.

Or parallel lines may not look parallel. Or two circles the same size that look different because of their contexts.

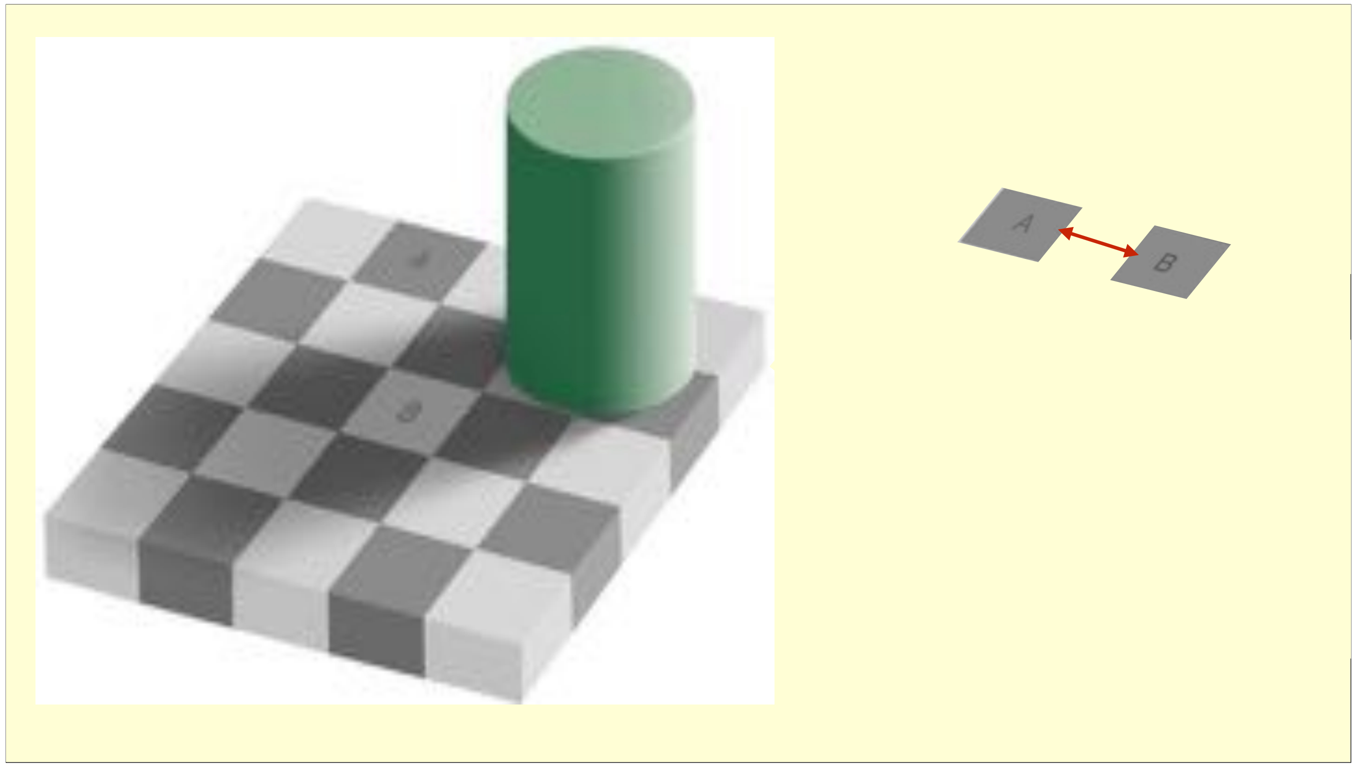


Or we start seeing black dots in a pattern where there are no black dots.

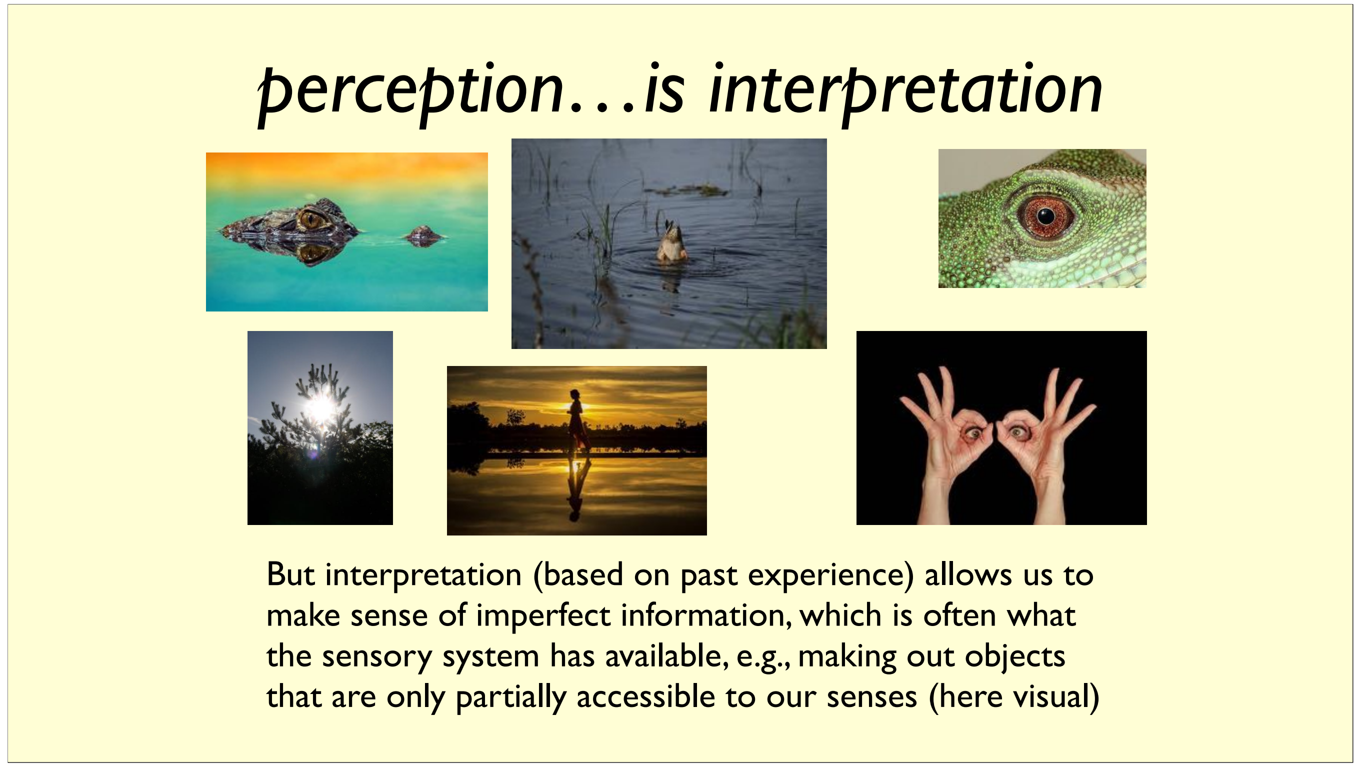


This is one of my favourites.
The story goes that the squares marked A and B are the same shade of grey.
That is clearly not so.

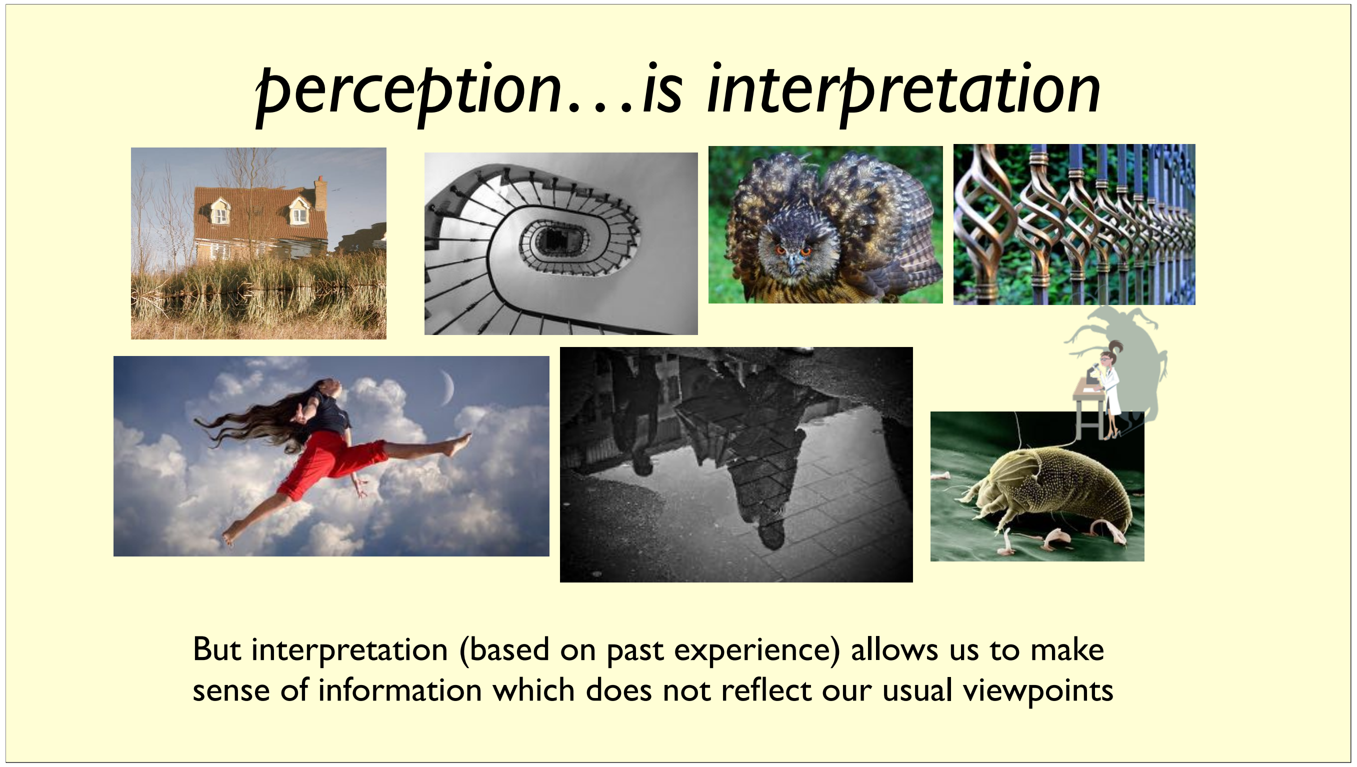
Anyone can see they are quite different.
I read of someone who was so convinced the squares were different shades that they photocopied the image, and cut out the two squares to compare them directly.
This is what happens if I remove the context…



(So, anyone can see they are quite different?)

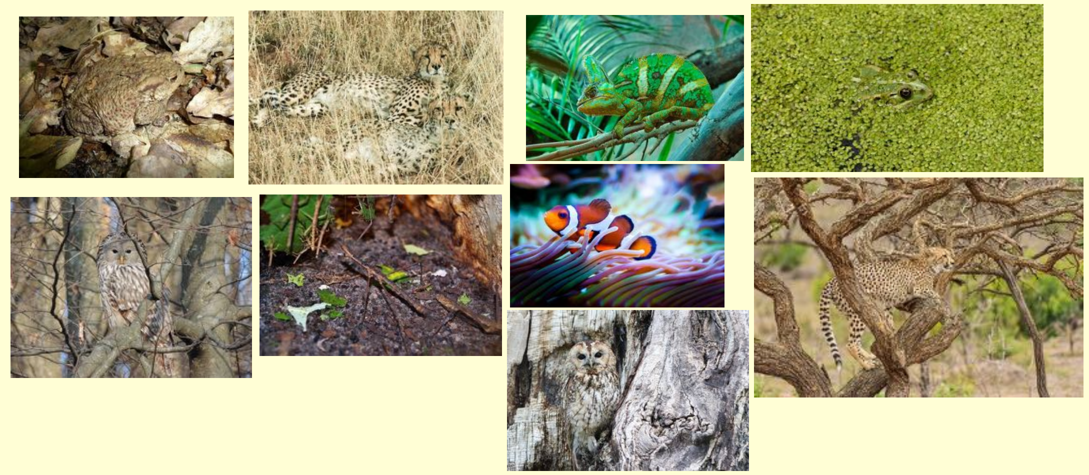


Usually, however, our skills are amazing.
Interpretation allows us to make sense of imperfect information, which is often what the sensory system has available, e.g., making out objects that are only partially accessible to our senses.



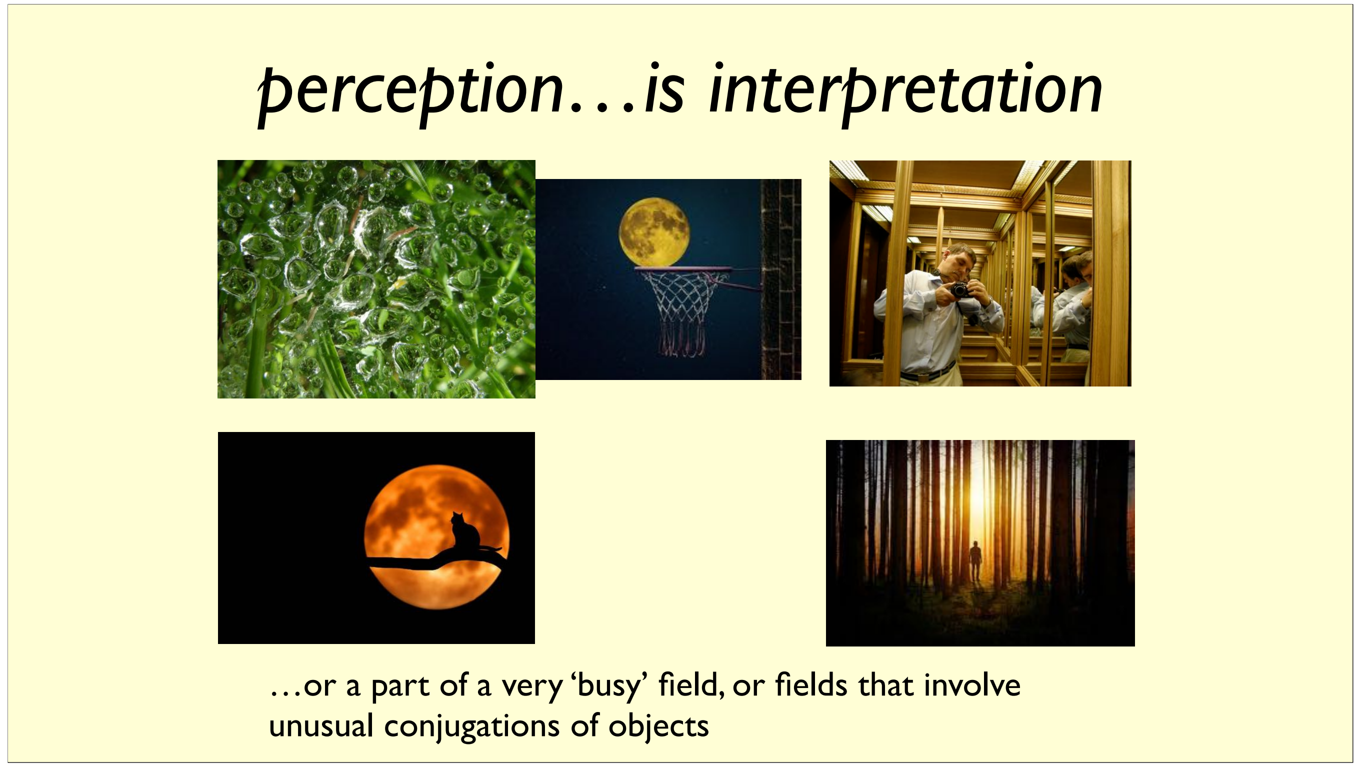
Interpretation allows us to make sense of information which does not reflect our usual viewpoints.

perception…is interpretation



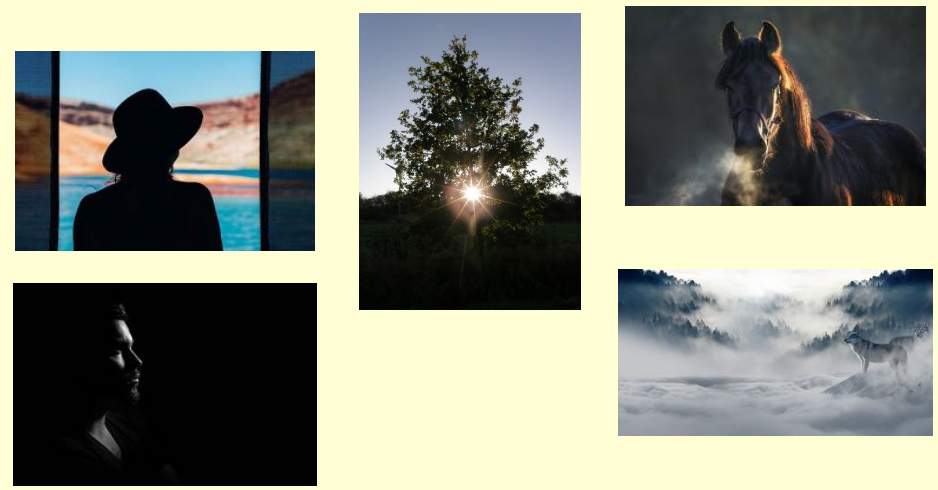
But interpretation (based on past experience) allows us to make fine distinctions by making out figures that blend into their backgrounds…

Interpretation allows us to make fine distinctions by making out figures that blend into their backgrounds.



Interpretation allows us to make fine distinctions by making out part of a very ‘busy’ field, or fields that involve unusual conjugations of objects.

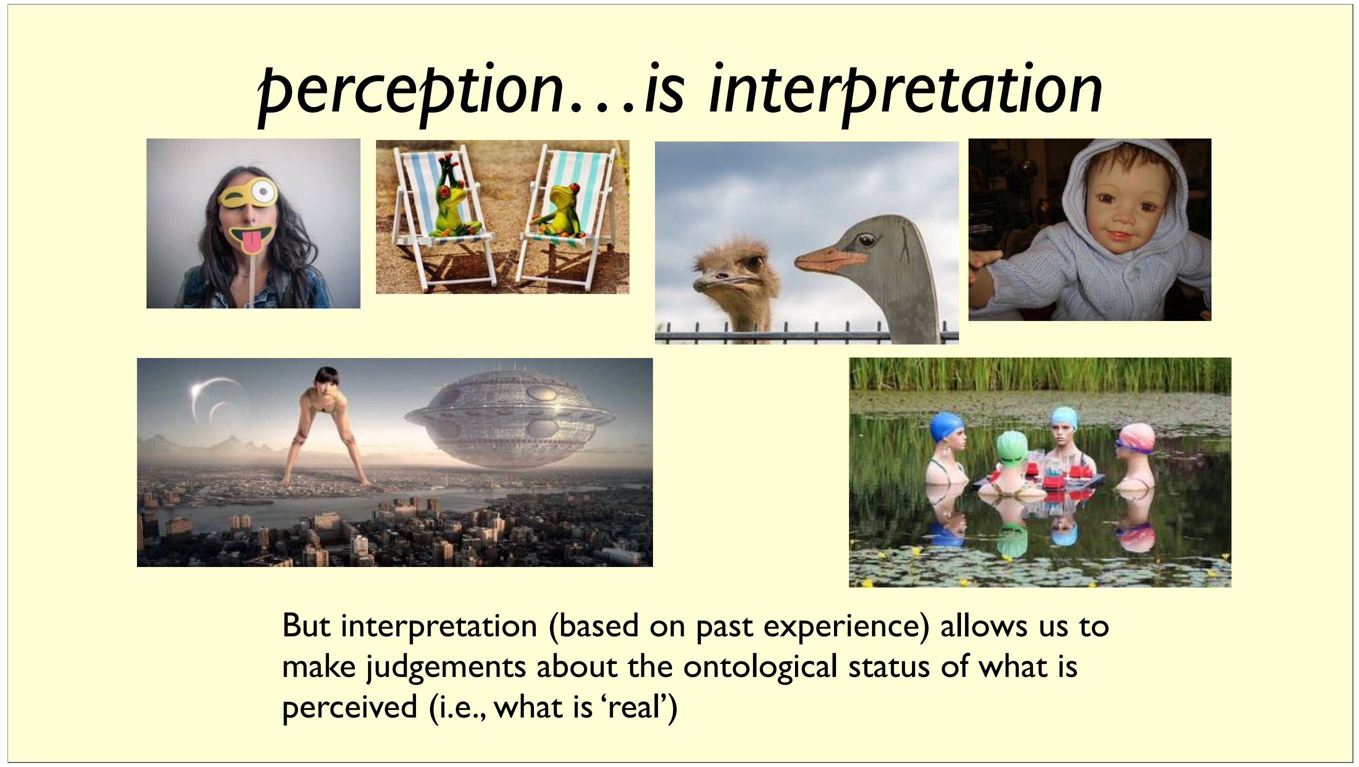
perception…is interpretation



But interpretation (based on past experience) allows us to make fine distinctions when observational conditions are poor.

Interpretation allows us to make fine distinctions when observational conditions are poor.

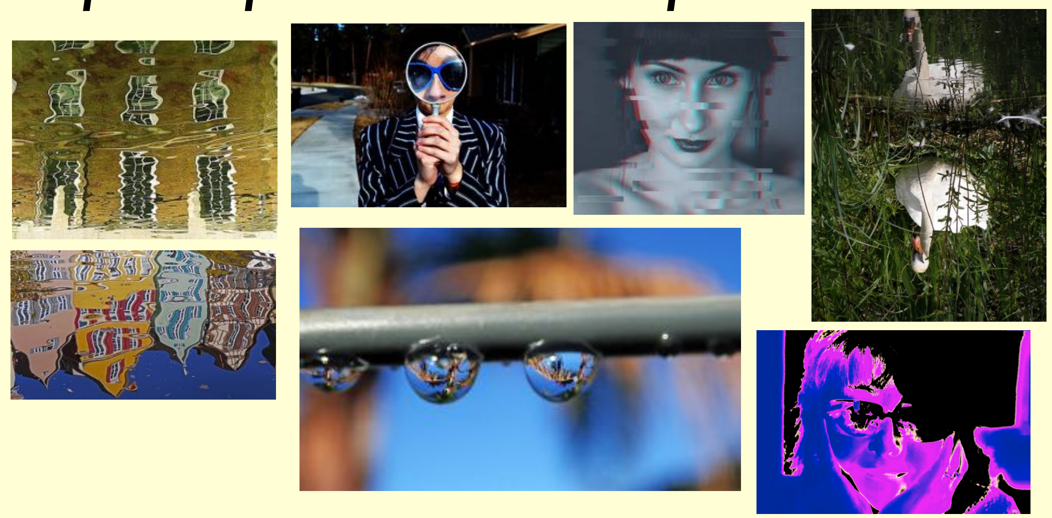
So we can interpret an image of a horse when only certain arbitrary parts of it are strongly illuminated. Think of the processing that is going on here - or how you can recognise the figure of a woman from a silhouette that gives so little information.



Interpretation also usually allows us to make judgements about the ontological status of what is perceived.

In all these cases your brain is applying learning: it had previously changed your potential for behaviour in response to experiences. If it does not seem that way it is only because it all happens automatically and quickly, and because it is hard to remember what it was like when we were born and the world was just a chaotic mess of undifferentiated colour, shapes, sounds and movements. But we have all learned to make sense of sensory date in order to perceive the world. We construct an internal, mental model from sensory information interpreted in terms of brain structures we have built from past experience.

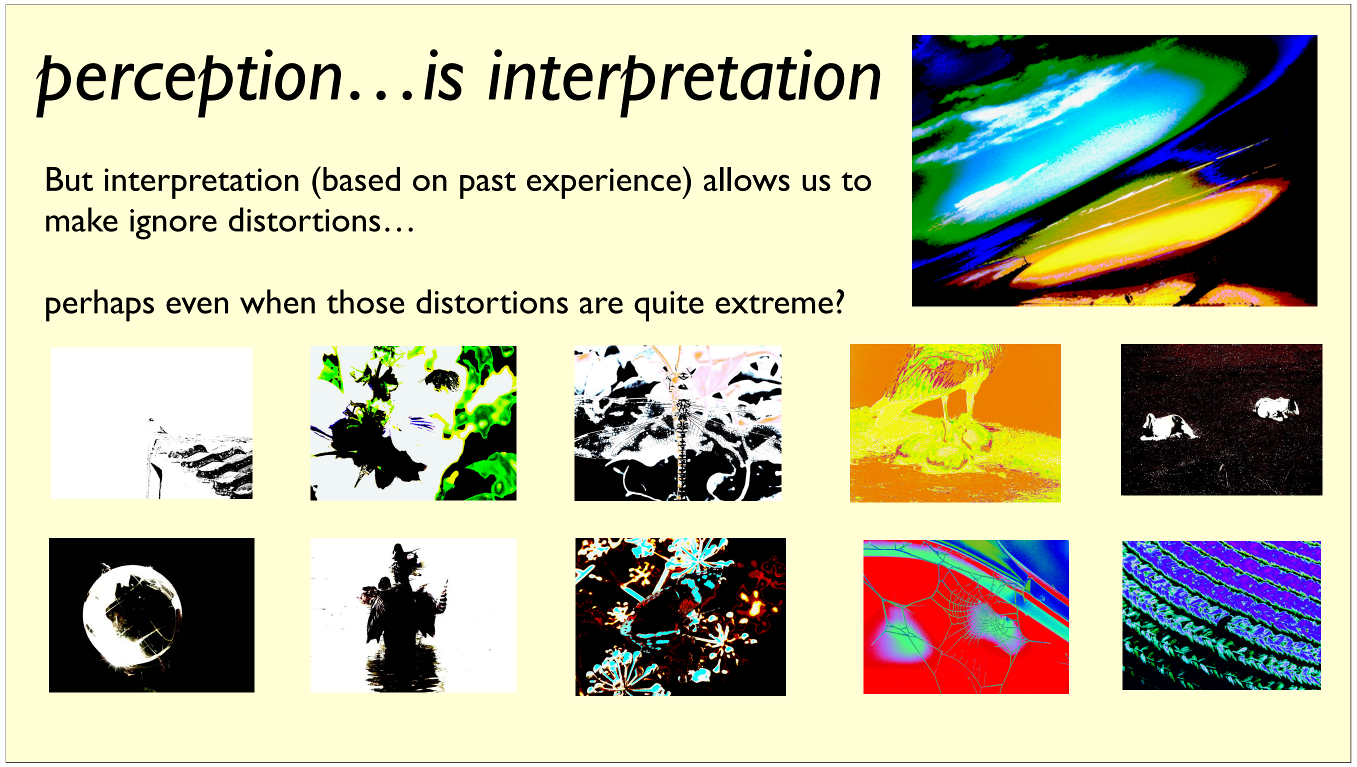
perception…is interpretation



But interpretation (based on past experience) allows us to ignore distortions

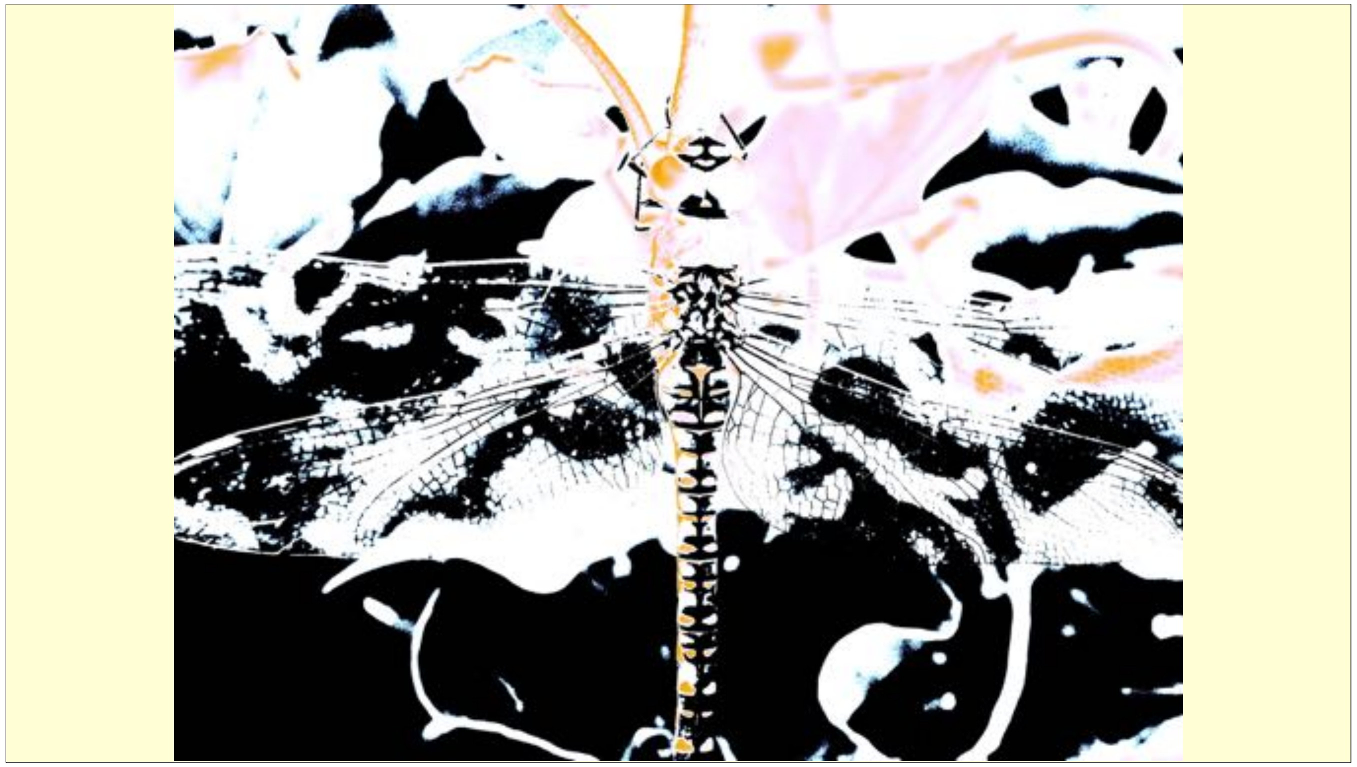
And interpretation often allows us to ignore distortions.

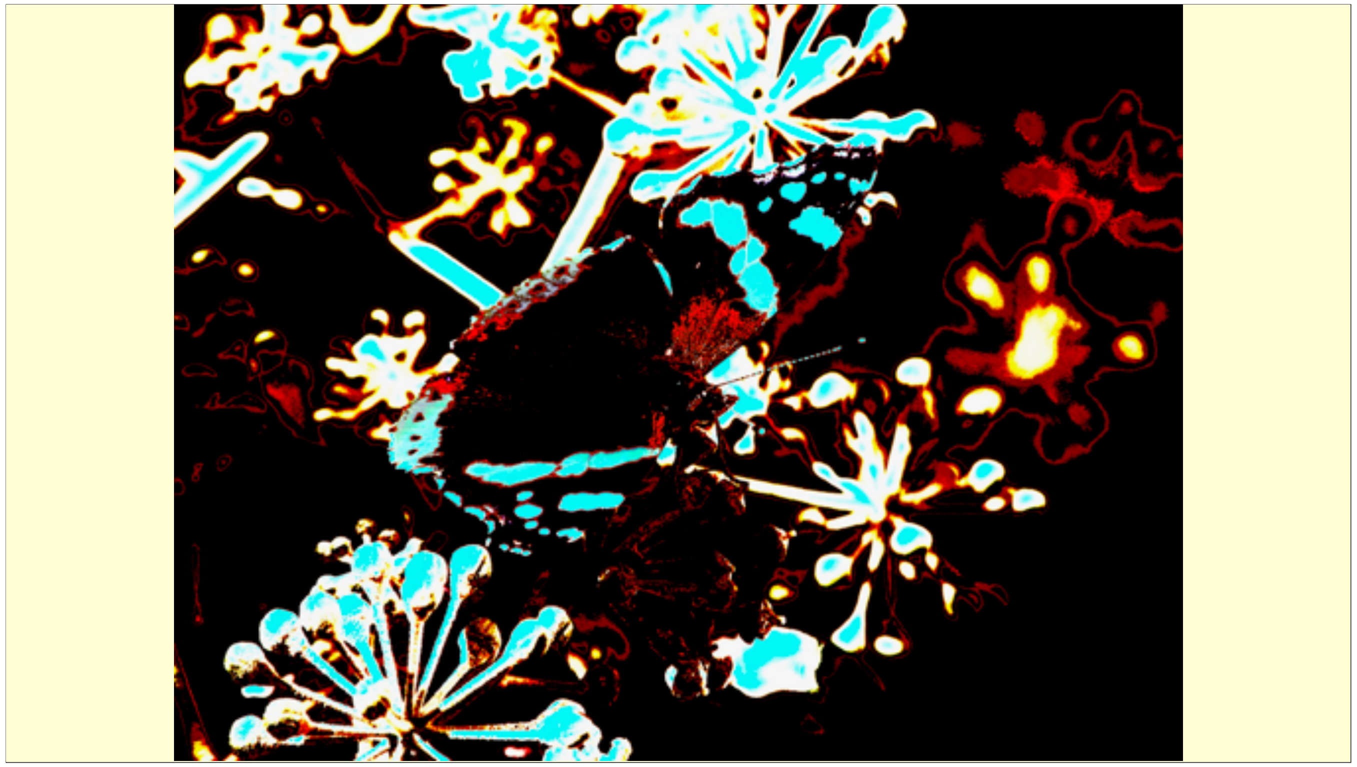
Again this is often immediate and automatic, unless the distortion is extreme.

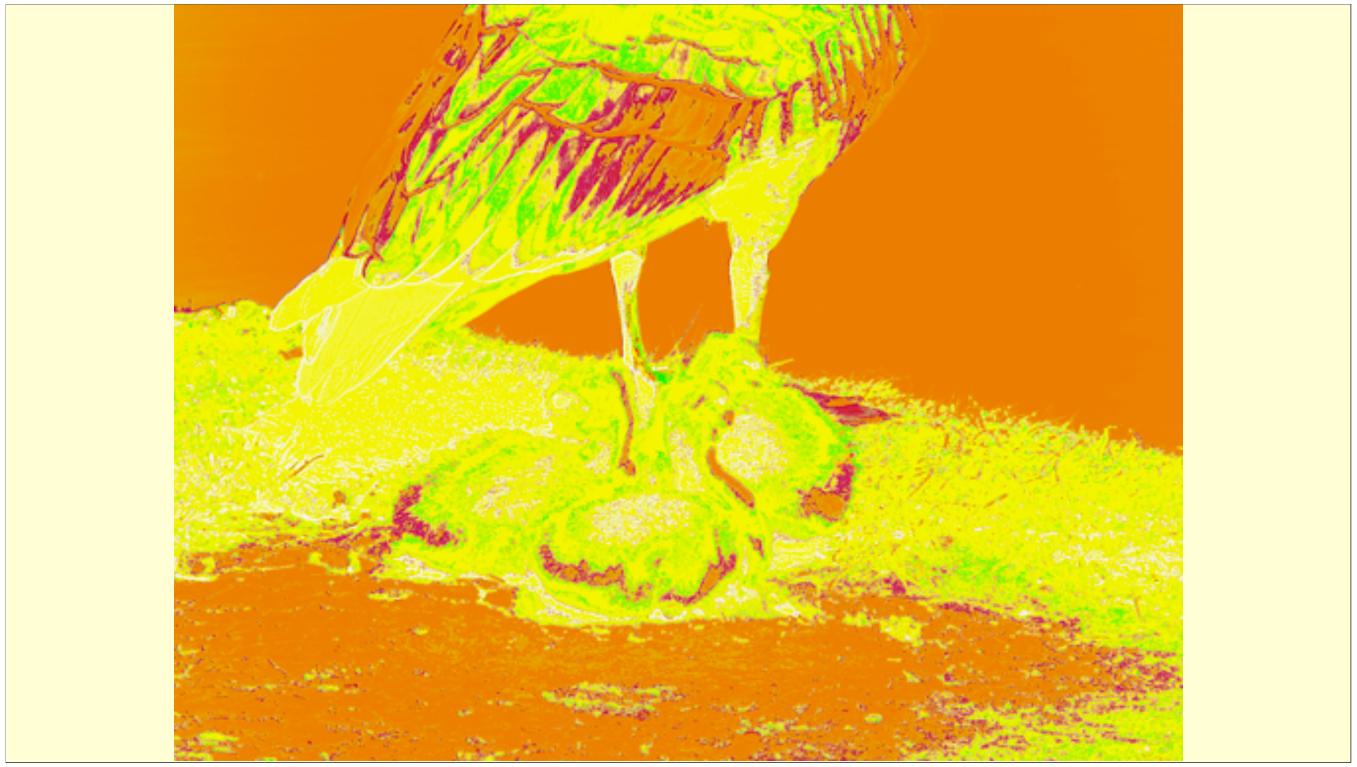


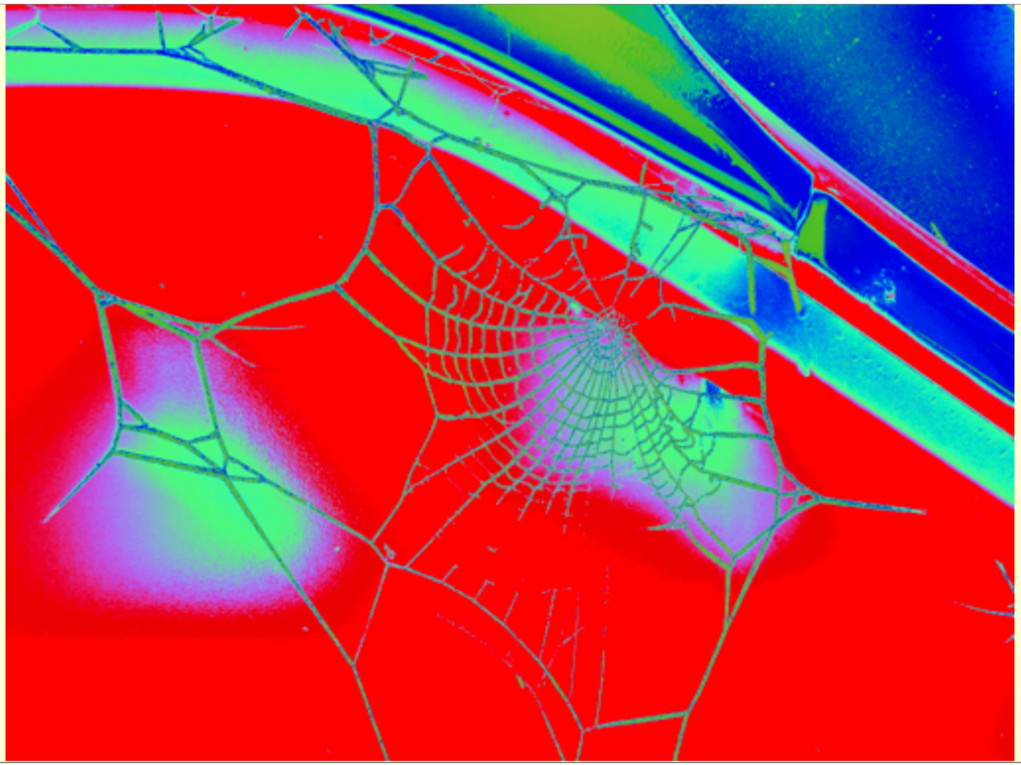
Of course there is a limit to that, and I wonder how those of you who took a look got on making sense of my deliberately distorted photographs?
[https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See 'Distorted images']

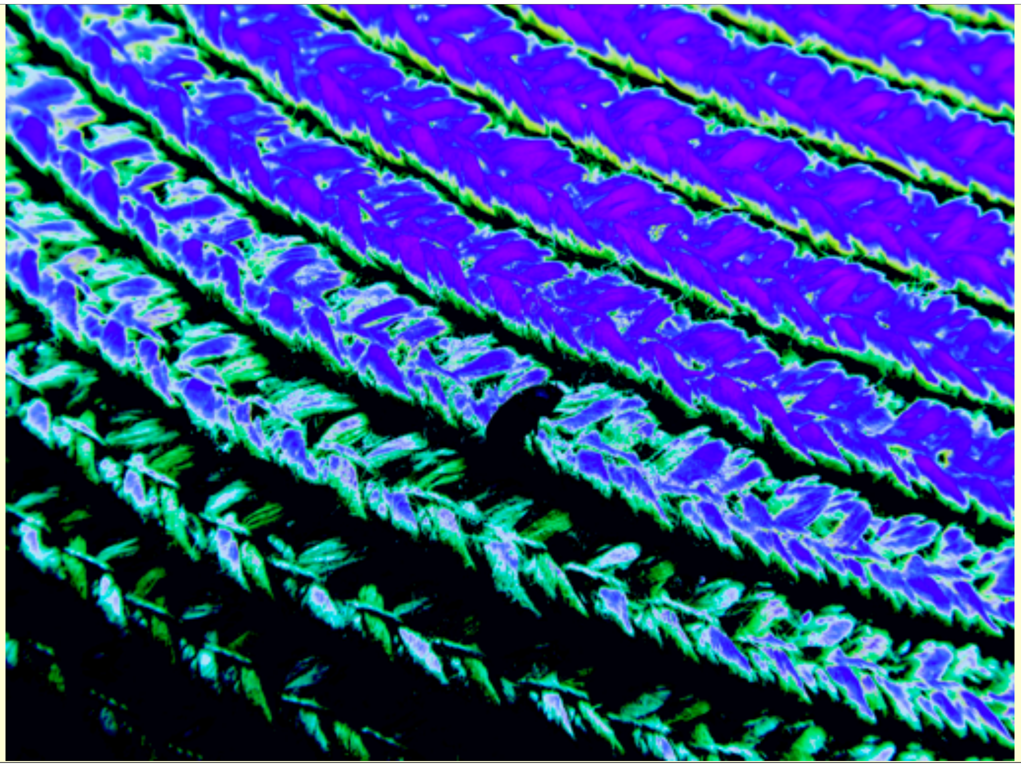
After I made these, I wondered if I had made them too obvious as I could still see what they were. But, of course, I was not able to see them as someone seeing them afresh would - I could not unlearn my prior knowledge of what the images were.

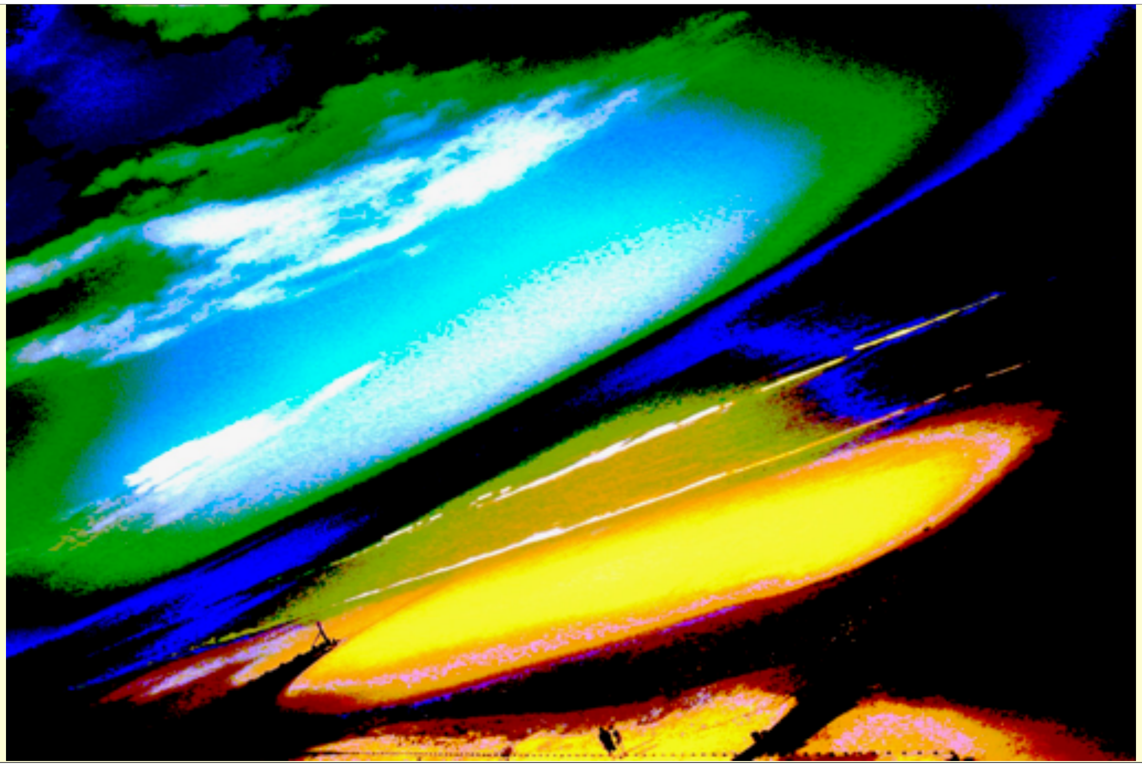




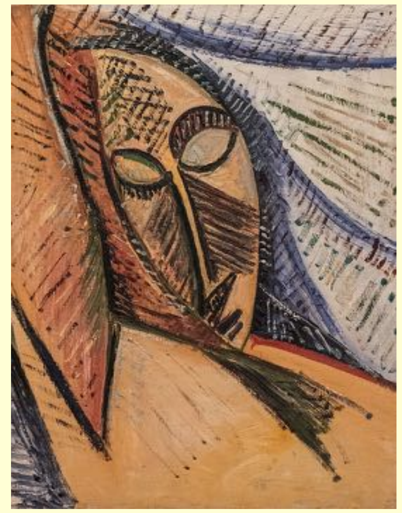








natural?

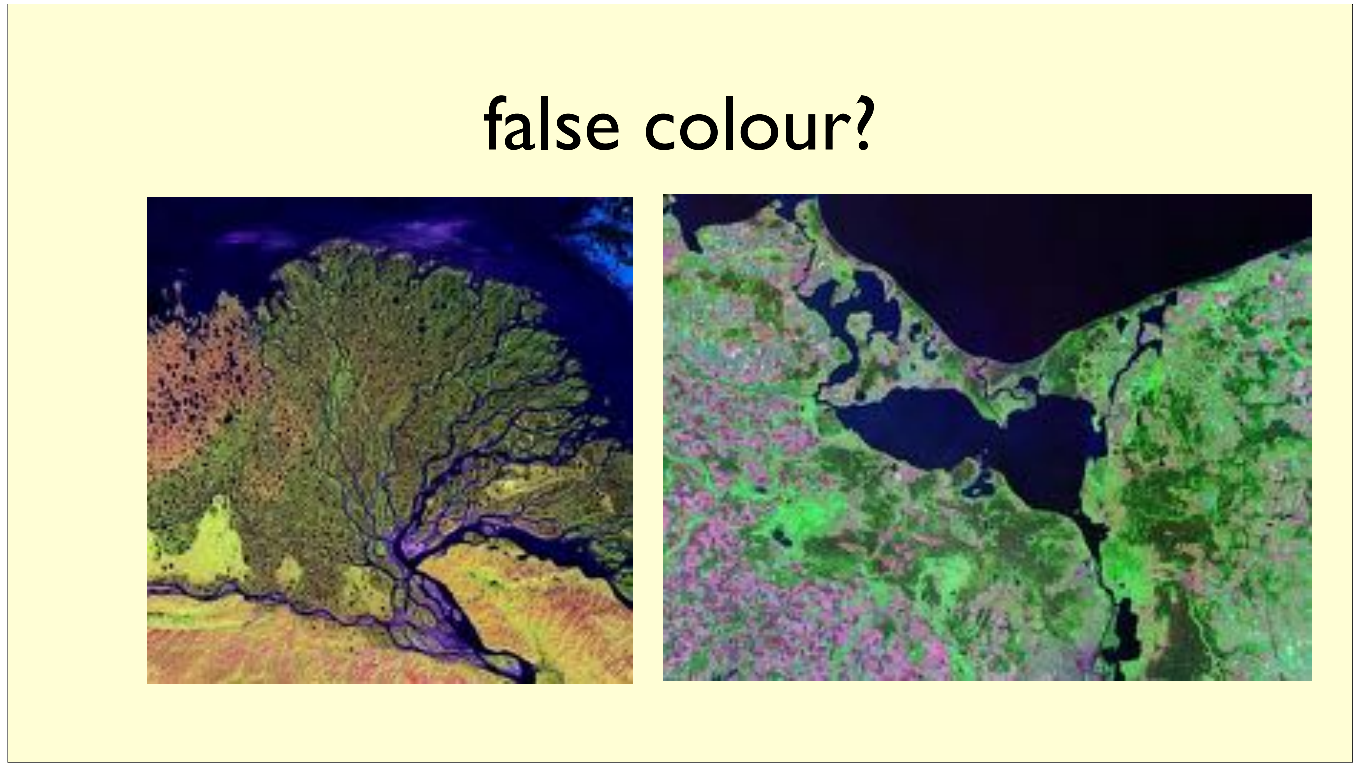


We can learn to interpret as natural scenes in representations that actually are not natural at all.

There is the story told of the man at an exhibition of Picasso's work, who was unimpressed with the lack of realism in the pictures. Supposedly the man told Picasso that his painting of a woman looked nothing like a woman. The artist is suppose to have replied, 'well, what does a woman look like?', at which point the man took a photograph out of his wallet. 'This is my wife, this is what a woman looks like.' Picasso asked 'is your wife really like this?' 'Yes', the man replied. 'Your wife', retorted Picasso, 'is rather flat and very small'.

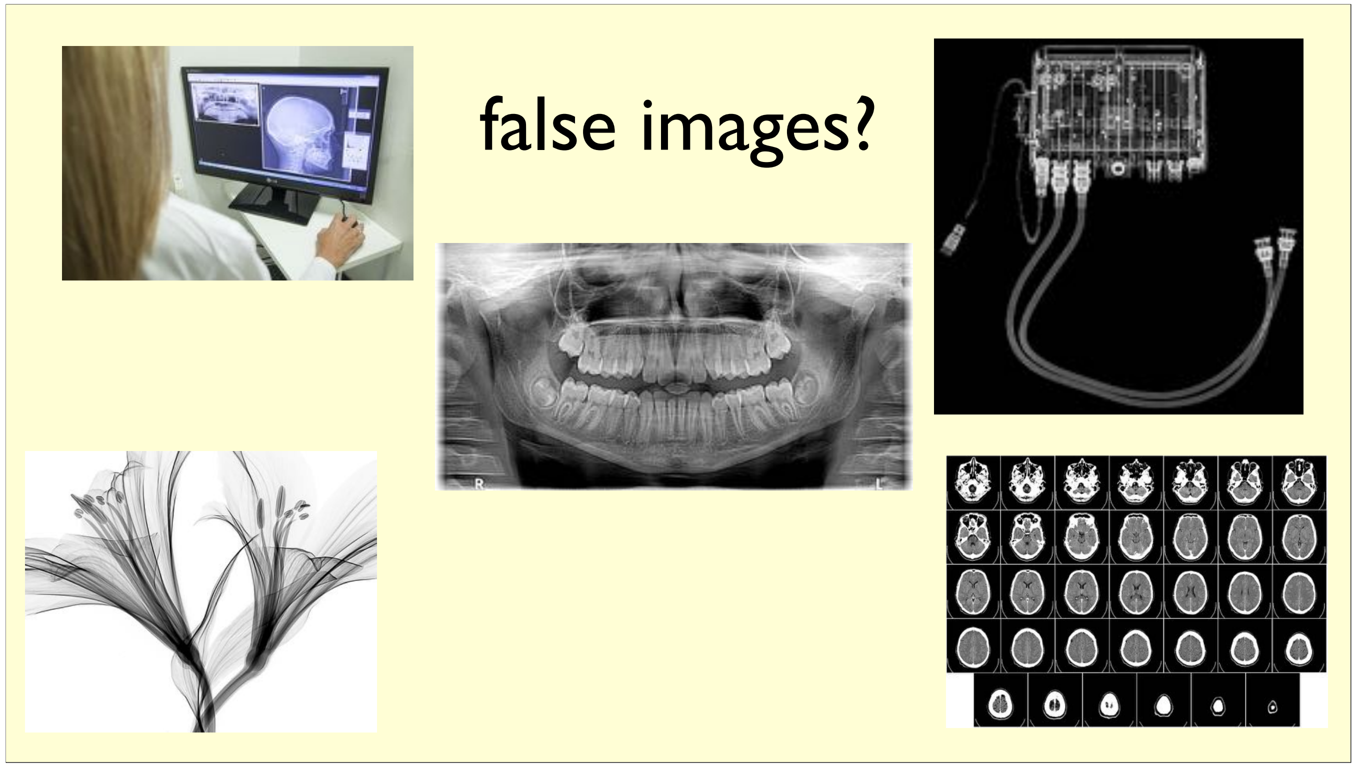
Perhaps partly we deal with monochrome images well, because they are familiar from our culture, But also, in very low light conditions we only see in back and white as rods in the retina are much more sensitive to light than the cones. At night we do not assume that colour has gone from the world, we ‘know’ that if we turn on a light the colours will still be there.

So, we do not immediately see this holiday snap as unnatural.
Yet this is more realistic - with some colour.
Or perhaps this?
Or this?
We are use to adapting to all kinds of light conditions - I am no longer sure which of these is the most natural representation!



The colours we see are somewhat arbitrary, depending on the frequency responses of titre types of cel lin the retina. Not all animals see in colour, and some are tuned to different frequencies to us Some insects have four different types of colour detectors [i.e. tuned to different frequency bands], and some see into what we call the ultra-violet, which is ‘invisible’ to us.

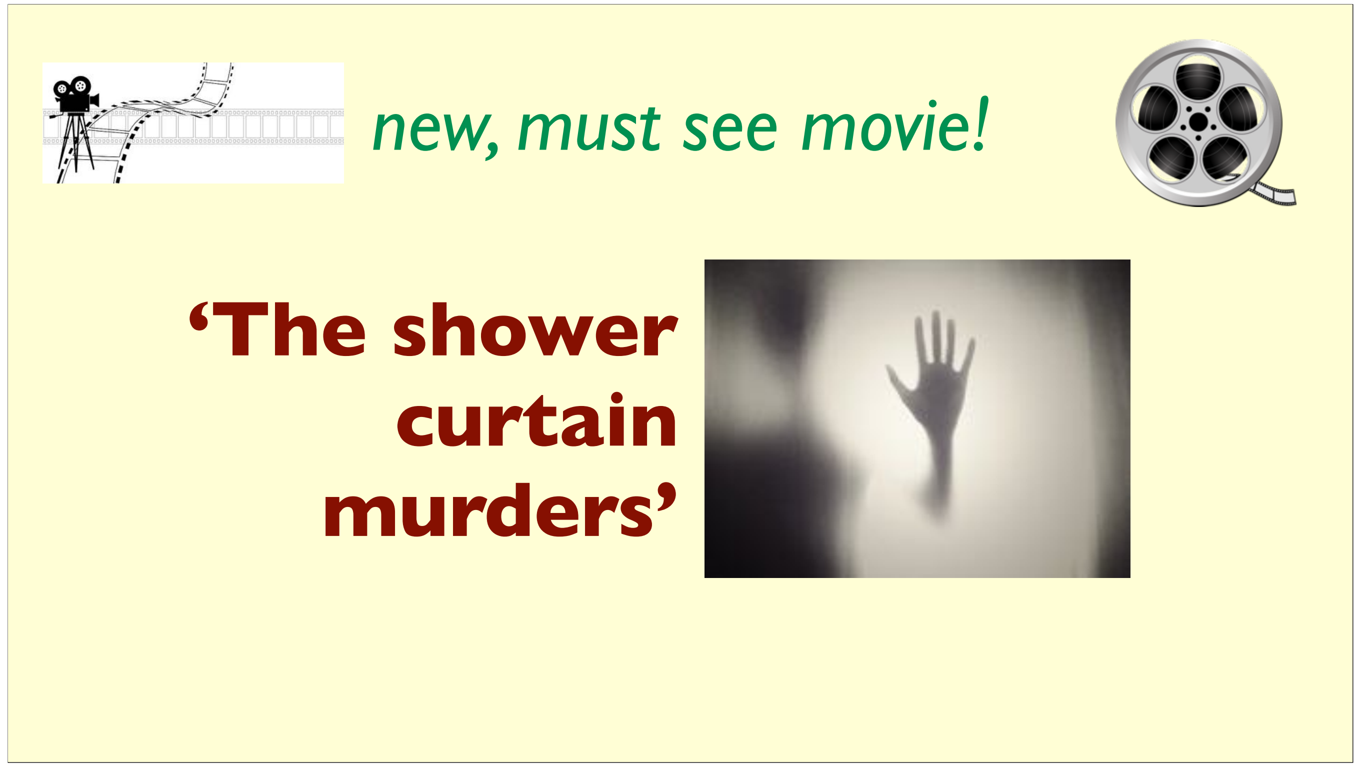
In a similar way, satellites may collect data from frequencies outside the range of human vision - and the data are coded in false colour so we can see patterns.



Indeed, the right technology enables us to see X-rays, but in a sense this image is no more artificial than the image our visual systems constructs from the light rays detected.

I wonder how you interpret this image?

And what about now?



And now?

new, must see movie!

‘They came from another galaxy’

Does this change what you see at all?

WM: the bottleneck

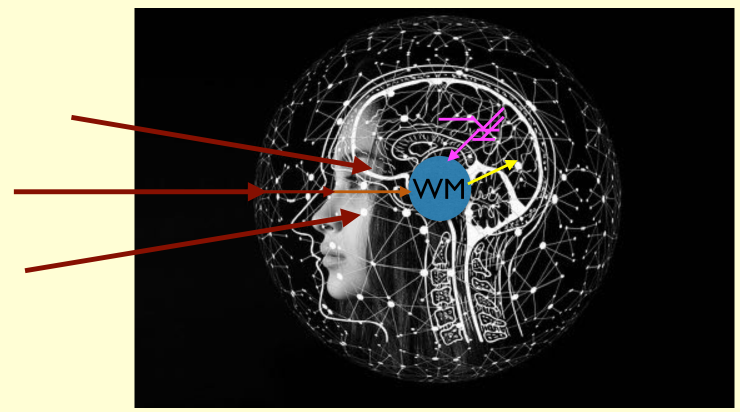
Working memory can be considered the focus of conscious thinking

WM has a very modest capacity ('±7 chunks of information')

Most sensory information does not reach WM:

that which does has already been interpreted

WM can draw upon representations 'in memory'



What we perceive is constructed understanding, it is the outcome of an analytical process allowing us to make sense

I have mentioned that these processes are largely preconscious, but, of course, perception occurs when the processed information reaches consciousness. Out conscious thinking is strongly linked to a part of the cognitive system known as working memory. Probably the most important things we have learned about about working memory are about its capacity limitations.

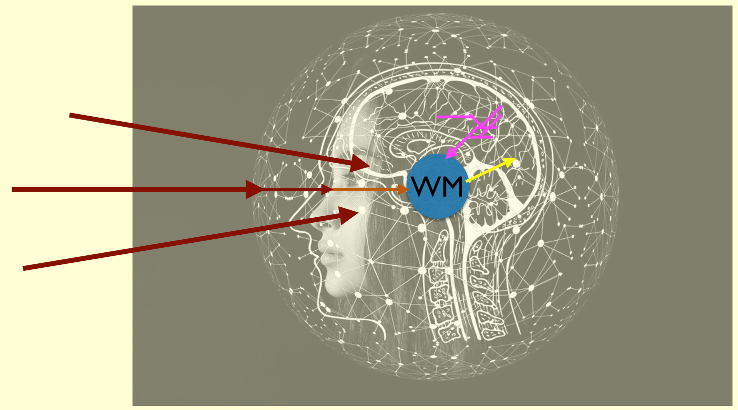
Much information reaching our sense is selectively filtered out so that what we perceived has not only been interpreted, but has been identified as currently most important to pay attention to.

In one sense it has a tiny capacity, so we can only mentipulate a limited number of items at once, however those items are not of fixed size.

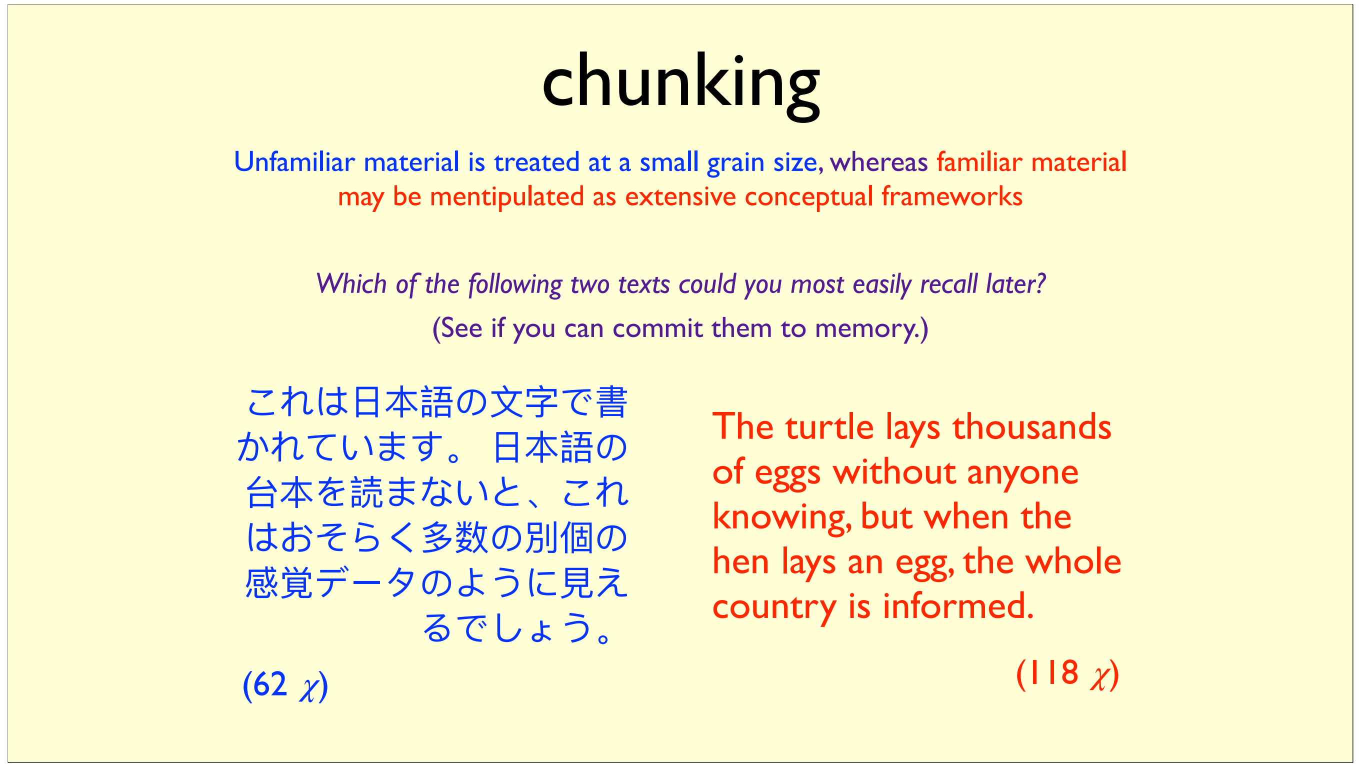
so learning is conservative

as (i) sensory material reaching working memory for conscious processing has a already been made sense of (interpreted, so perhaps distorted) in terms of expected patterns

(ii) unfamiliar material is treated at a small grain size, whereas familiar material may be mentipulated as extensive conceptual frameworks

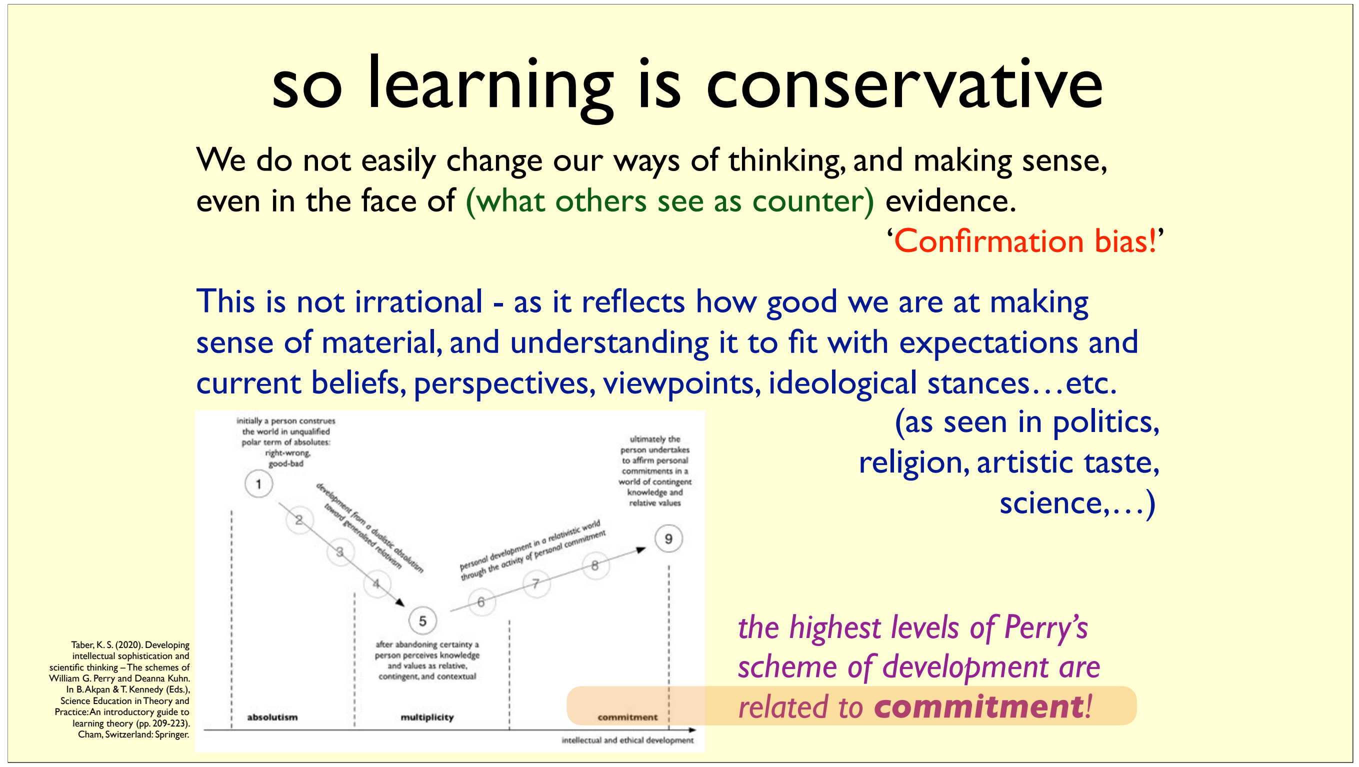


A key determinant of the size of the items, or chunks of information, mentipulated in working memory is their familiarity. Very familiar material may be structured into extensive chunks of information, whereas novel information needs to be considered bit by bit.



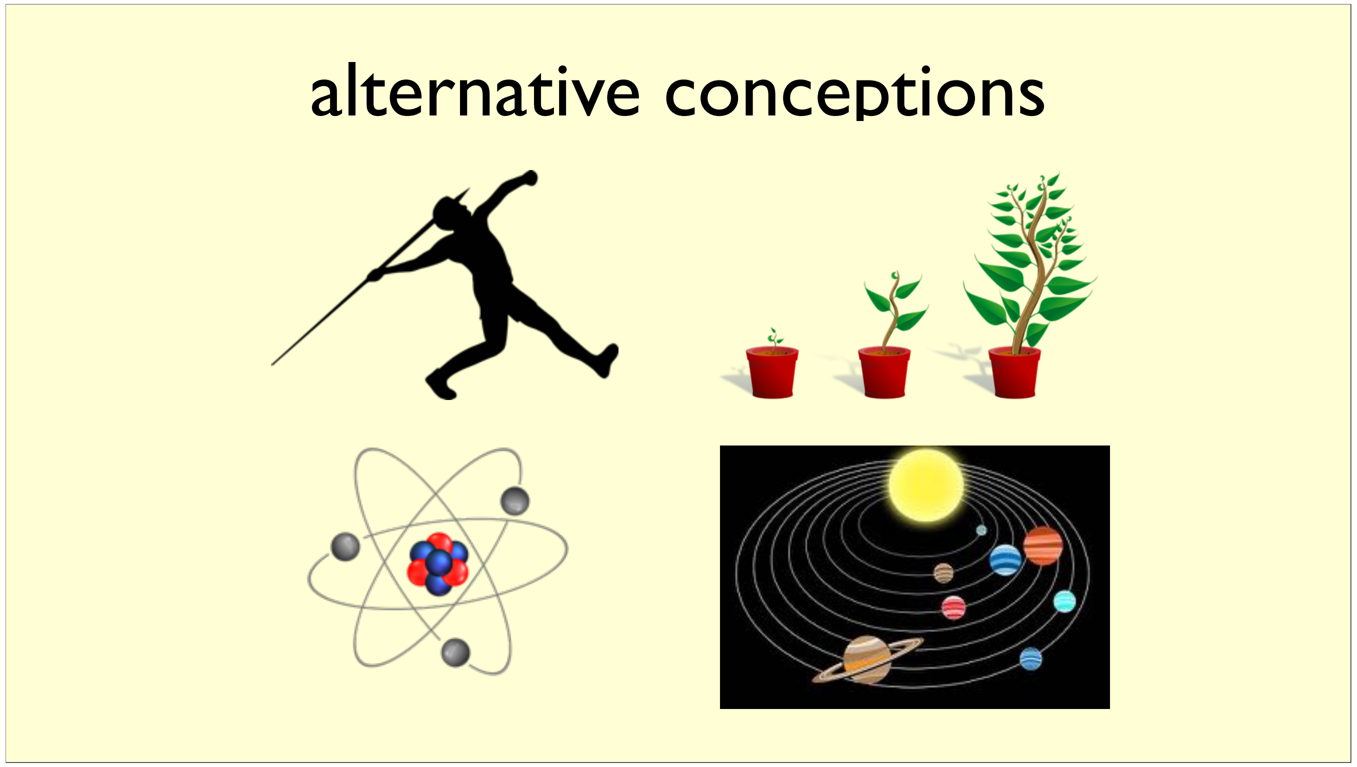
If you visited the lecture preview and viewed these two texts earlier, then - unless you read Japanese - I suspect that you thought it would be much easier to memorise one than the other.
[https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See 'How good is your memory?']
Indeed, you would have found it easier to memorise the text which technically had the most information content, that is, about twice as many symbols [this assumes you read each Japanese character as a single unit!], as you will have much more easily made sense of it.

That is, you were able to interpret one of these sequences of symbols in terms of prior learning, as it related to previous experience, so it was meaningful. Unless you read Japanese script, the other is subjectively much more complex and abstract.



This has the consequence that we are all conservative learners. There is a bias in our thought processes towards well-established ways of thinking. We find it much easier to learn material when it fits with existing understanding as prior learning provides a framework within which it makes sense.

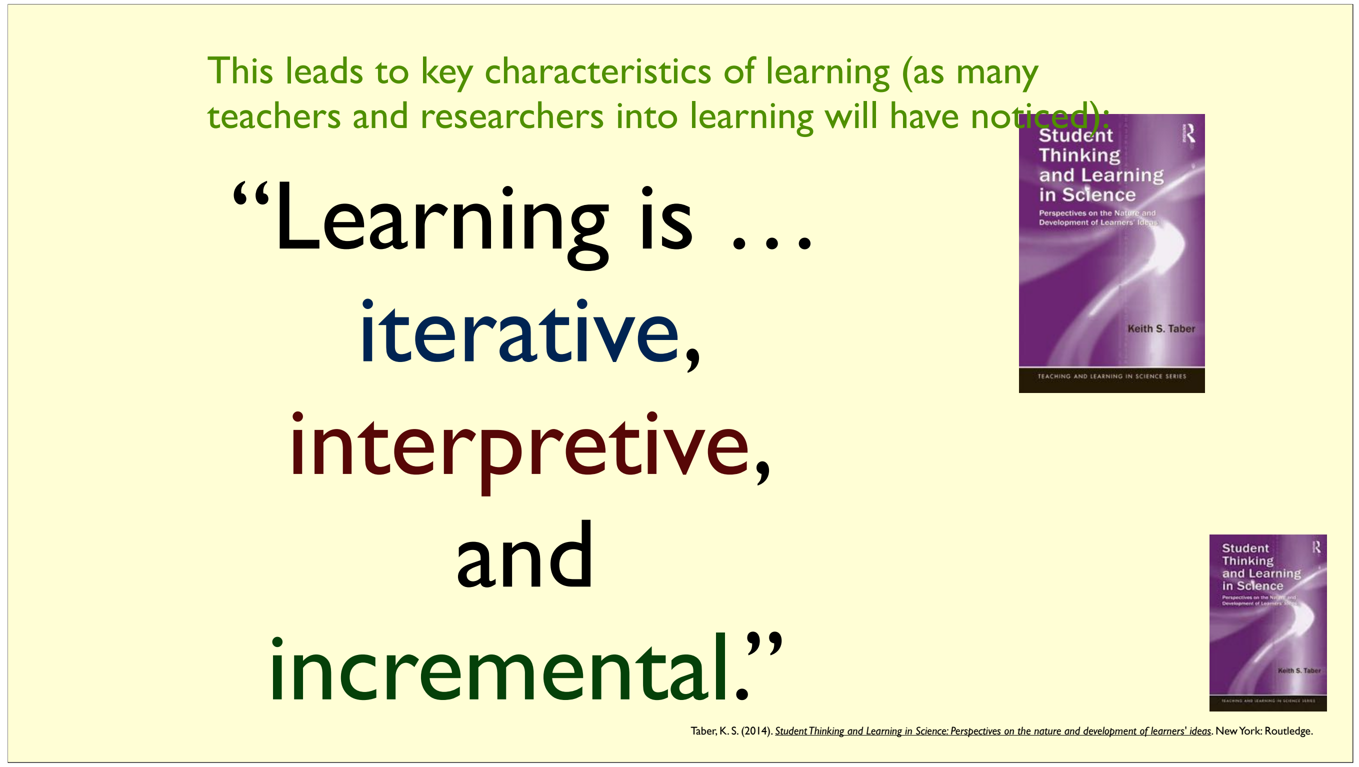
People generally do not change their minds easily, and sometimes seem blind to what others feel is obvious evidence that they are wrong



We know that our sense-making apparatus, with its effective pattern-recognition ability, sometimes develops flawed understandings of the world. Children commonly go to school with ideas that are either contrary to, or inconsistent with, what they will be taught. In my subject, we find common alternative conceptions or misconceptions in areas such as force and motion, plant nutrition, atomic structure, celestial mechanics and indeed just about any science topic that researchers investigate!
[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/]

It is not just children. Adults may hold all kind of odd folk notions about broken mirrors, spilled salt, black cats, lucky horseshoes, lucky or unlucky numbers, and even the value of having a pregnant woman plant your pumpkin vines for you. People over-interpret sense data and spot patterns that are coincidental, and these can be built up into folk beliefs that become widely shared, with apparently confirming evidence given much more attention than counter-evidence.

Our systems for constructing understanding of a complex, messy, chaotic works help us make sense and cope with the world, but the cost we pay is that sometimes we spot false patterns and then use those to interpret future experience in ways that then reinforce those ideas.

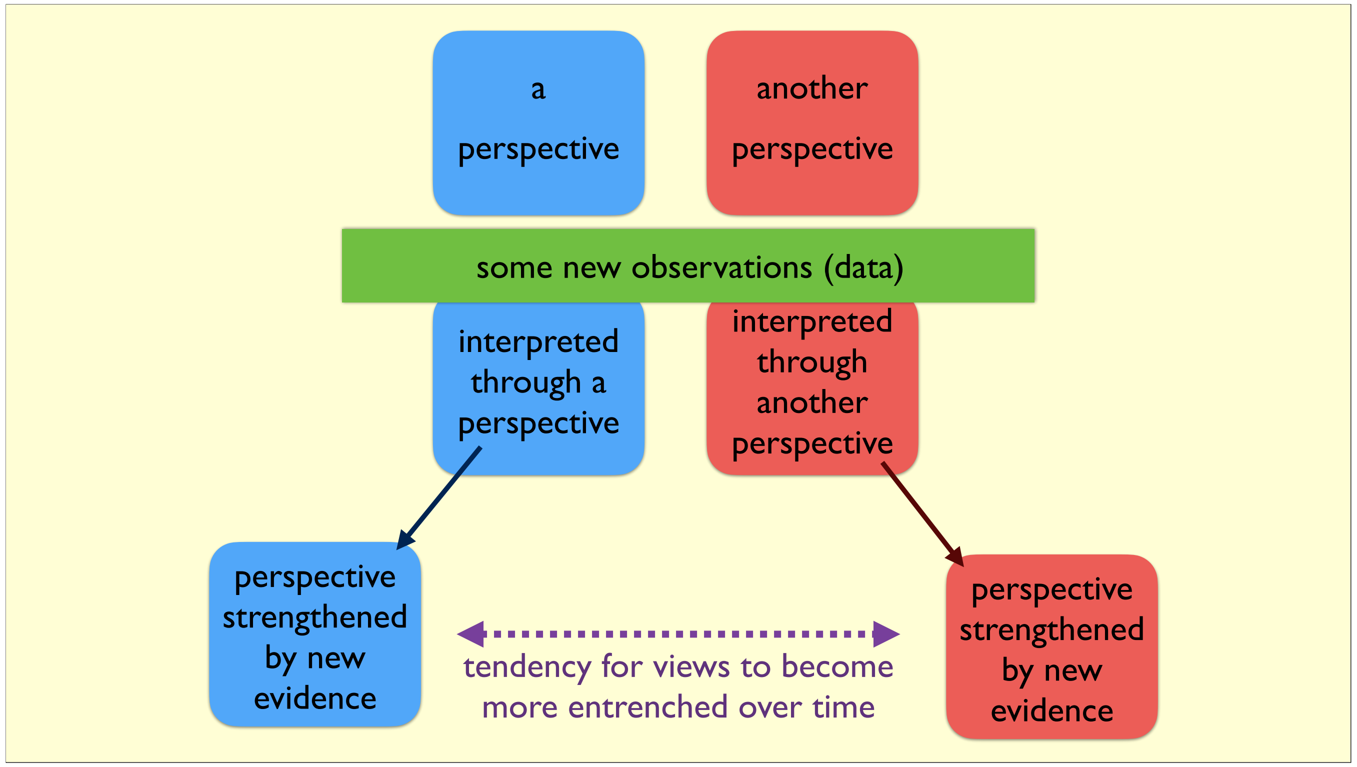


The outcome is that learning tends to be iterative, interpretive, and incremental. [https://science-education-research.com/publications/books/student-thinking-and-learning-in-science/]

It is incremental because our working memories can only cope with a small amount of new information at any one time.

It is interpretive because if our brains had not abstracted patterns from experience as the basis for making sense of the world, we would be like new born babies, living in a chaos of noises, colours, shapes, and movements that would overwhelm us, and which we could never consciously cope with. The cost of our brains doing so much preconscious work for us, is that sometimes it misleads us.

It is iterative, because all that we learn adds to the fund of interpretive resources, and as our learning is biased by what we already know, our understanding builds up iteratively.



This is why different people can interpret the same information in such different ways.

What is memory?

- A discrete faculty of the brain where knowledge and experiences are stored
- Memories are laid down at one point in time and may be accessed later (unless we forget).
- A memory is a stored experience.
- Remembering can be understood as bring a memory record out of storage.
- 'Purpose' (function selected for in evolution): to keep accurate records of the past.

- A ***distributed*** function that influences perception.
- Memories are consolidated over time, and can become integrated - they are ***modified*** whenever activated.
- Experience cannot be stored, only ***represented***.
- Remembering is a process of ***reconstruction*** informed by memory traces.
- 'Purpose' (function selected for in evolution): to provide a model of the world to guide current action. [This is inferred not empirical]

In terms of long term memory we need to overcome the naive idea that is is a discrete part of the brain for storing things.
Rather research shows us that:
[e.g., https://science-education-research.com/learners-concepts-and-thinking/memory/remembering-and-forgetting/]
* Memory is a distributed function that influences perception - in a sense memory influences what we perceive as the processing apparatus that interprets perceptions for us has been shaped by our previous experiences [it is in a sense part of our memory].
* Memories are consolidated over time, and can become better integrated - they are modified whenever activated. It is possible to plant false memories, for example, so that eye witnesses report in all good conscience remembering things they never originally saw.
* Experience cannot be stored, only represented. Knowledge is not really stored in memory, but is represented in a form such that we can reconstruct it.
* Remembering is a process of reconstruction informed by memory traces. There is much research showing that what seems a coherent complete memory is often pieced together, with the brain making sensible assumptions, guesses, to fill in missing details. The person remembering may have no idea which part of a memory is just this filling-in of missing details.

Familiar?

A

The koi lays thousands of eggs without anyone knowing, but when the hen lays an egg, the whole country is informed.

B

The turtle lays thousands of eggs without anyone knowing, but when the hen lays an egg, the whole country is informed.

C

The hen lays thousands of eggs without anyone knowing, but when the turtle lays an egg, the whole country is informed.

D

The turtle lays thousands of eggs without anyone knowing, but when the tortoise lays an egg, the whole country is informed.

Anyway, now it is time to test your memory. Earlier, you saw one of these texts.

Can you remember which one?

How confident are you?

Familiar?

A

これはアラビア文字で書かれています。 アラビア文字を読まない場合、これはおそらく多数の別個の感覚データのように見えるでしょう。

B

これは漢字で書かれています。 中国語のスクリプトを読まない場合、これは多数の個別のセンスデータのように見える可能性があります。

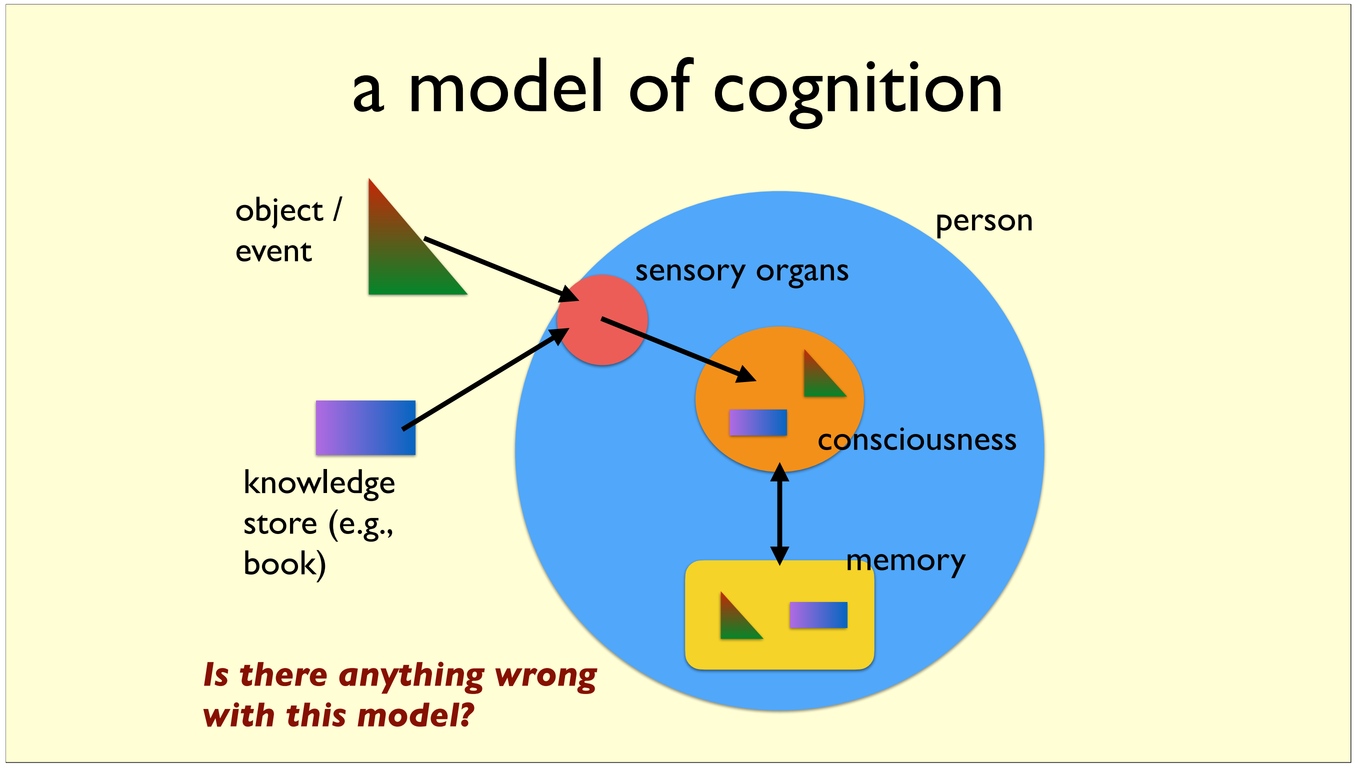
C

これは日本語の文字で書かれています。 日本語のスクリプトを読まないと、これはおそらく多数の別個の感覚データのように見えるでしょう。

D

これは韓国語のスクリプトで書かれています。 韓国語の台本を読まないと、これはおそらく多数の別個の感覚データのように見えるでしょう。

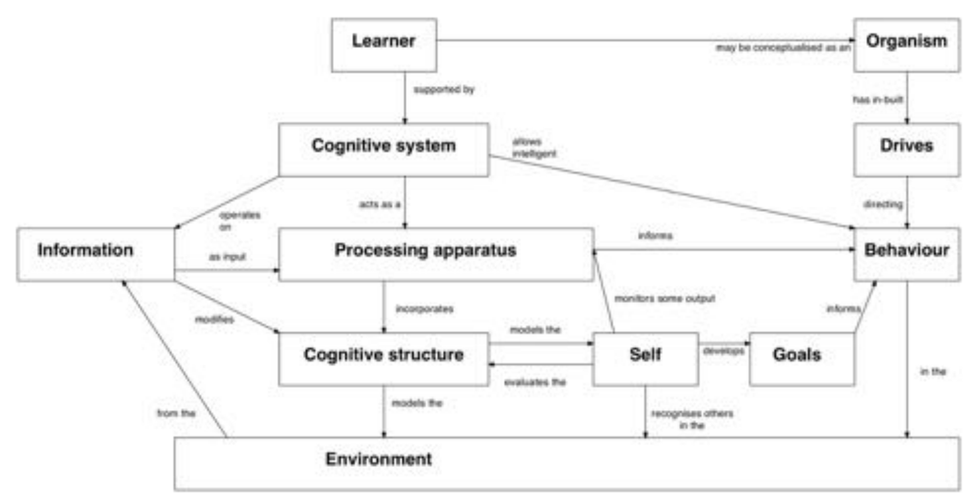
And Earlier, you saw one of these texts.
Can you remember which one?
How confident are you?

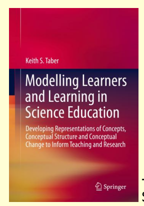


A naive view of cognition would suggest there is no difference in those two examples. If perception was just copying from the world to the mind, and memory just stored what had been experienced, then you should be able to simply pull out of memory an image of both of the texts you saw earlier. Unless you are one of those unusual adults that has what is known as a photographic memory, this is unlikely to be the case.

Humans also develop a sense of self, and discriminate themselves from the environment -

and learn to reflect on their own cognition!





Taber, K. S. (2013). *Modelling Learners and Learning in Science Education: Developing representations of concepts, conceptual structure and conceptual change to inform teaching and research*. Dordrecht: Springer.

As part of the iterative process of building up an internal model of the world, humans include themselves, and even their own thinking - supporting metacognition.

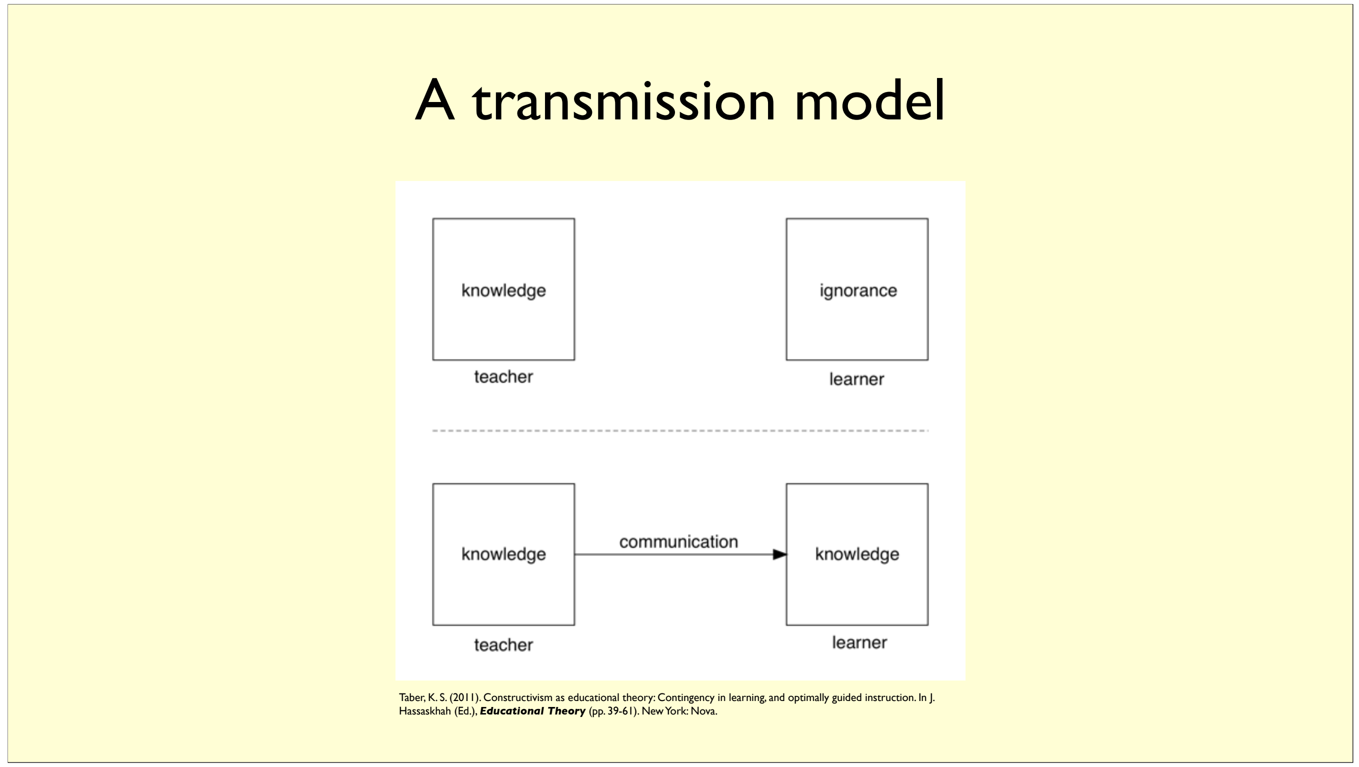
[https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/]

Humans also recognise certain other regular patterns in the environment as others like themselves, also able to think and feel and understand.

Culture - a means to avoid
everything having to work out
everything anew for themselves

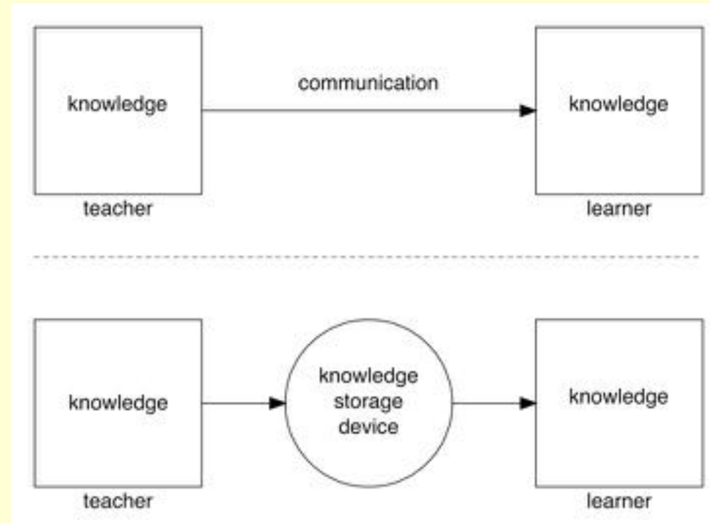
as long as we have
ways to communicate
what we have learnt

And this allows us to have culture as a means of seeking to sharing knowledge and understanding, so we can learn not only form direct experience, but from what others tell us about their experiences or about experiences of others they they have learnt about.



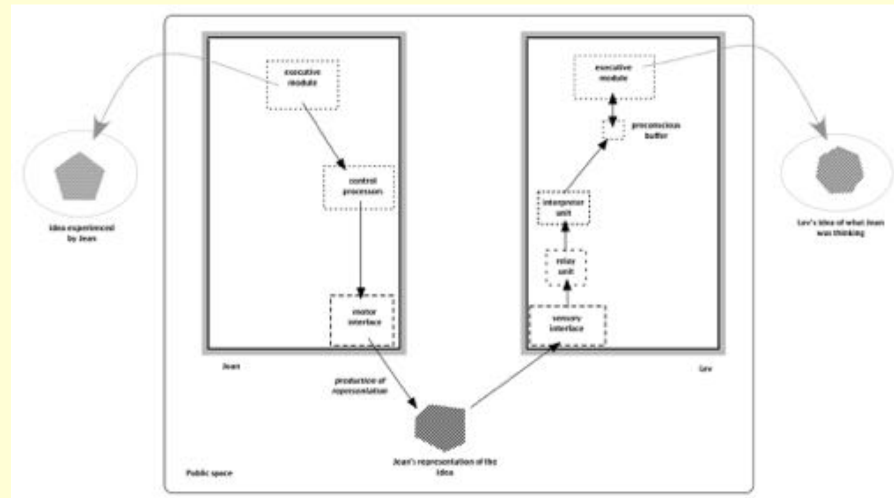
However, we have to be careful here. The point made about how we do not directly assimilate knowledge of the environment, but rather interpret experience, applies here as well.
[https://science-education-research.com/publications/chapters/constructivism-as-educational-theory/]

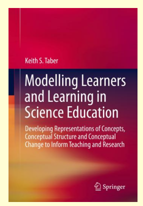
If knowledge can be copied, then perhaps it can be stored outside of minds?



We commonly think that we can share knowledge by storing it in books or other media - but this is over-simplistic. [https://science-education-research.com/publications/chapters/constructivism-as-educational-theory/]

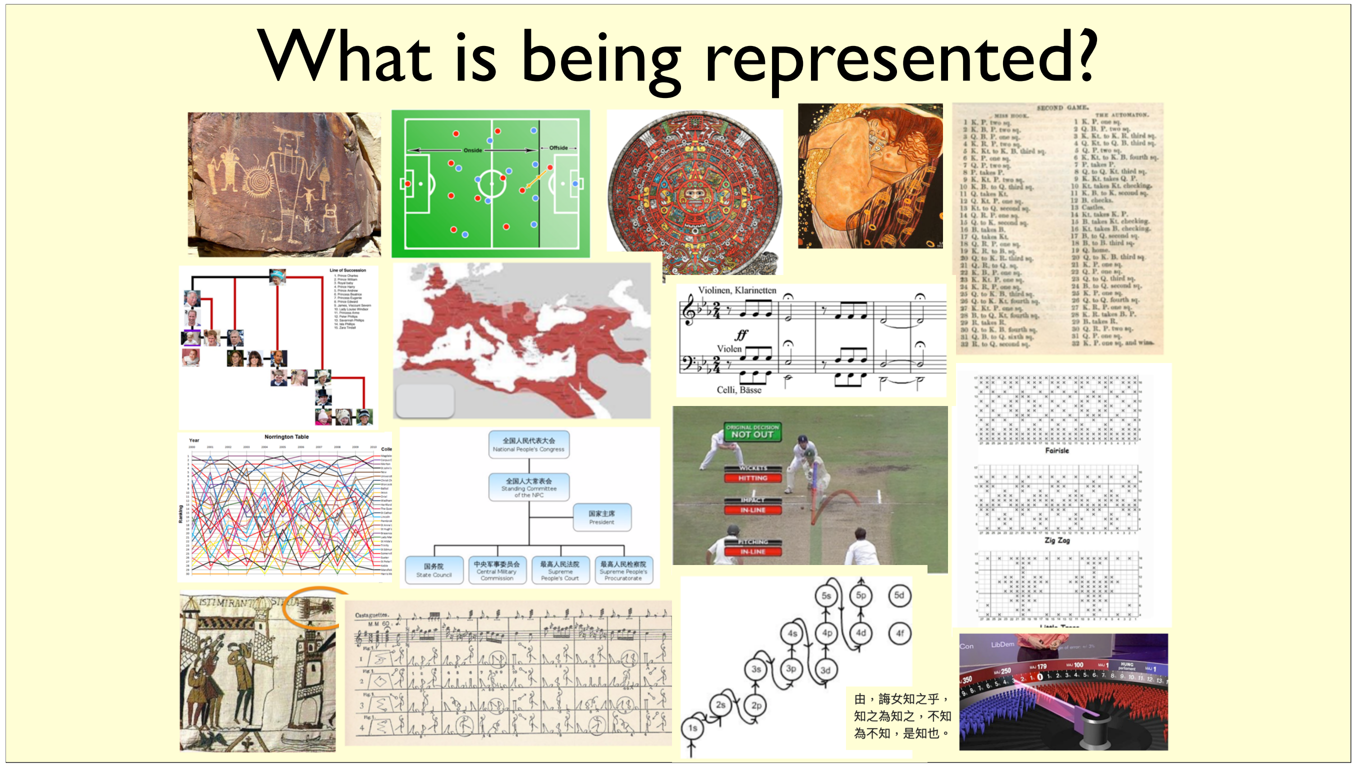
Communicating ideas





Taber, K. S. (2013). *Modelling Learners and Learning in Science Education: Developing representations of concepts, conceptual structure and conceptual change to inform teaching and research*. Dordrecht: Springer.

We can only represent what we think we know in some form such as writing or diagrams or speech, or perhaps like a bee by doing a dance, but this only works to a point, to the extent we share the language of communication. And we have to learn language or any symbol system, just like anything else.
[https://science-education-research.com/publications/books/modelling-learners-and-learning-in-science-education/]

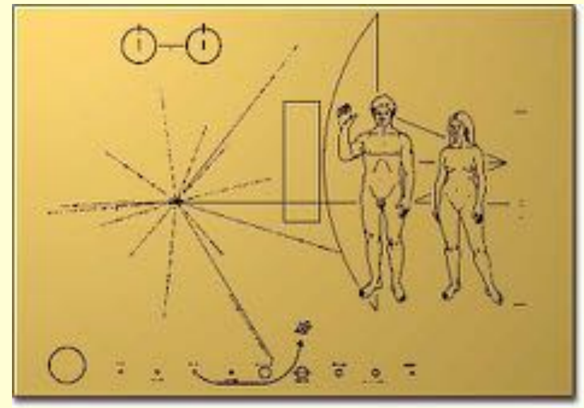


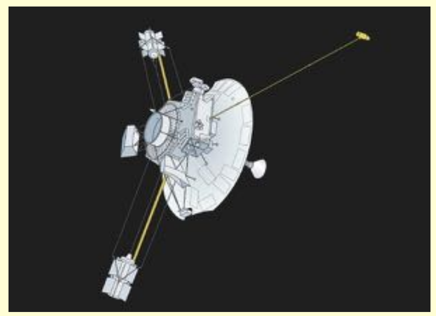
Here are some examples I used to use in teaching
[see also https://science-education-research.com/publications/miscellaneous/constructivism-good-bad-abhorrent/]
- because I taught classes with quite diverse national and disciplinary backgrounds, I knew that different examples would make sense to different members of the class, and others would not understand what was being represented in the different cases.

NASA's attempt to tell aliens about us

What was the message?

1972

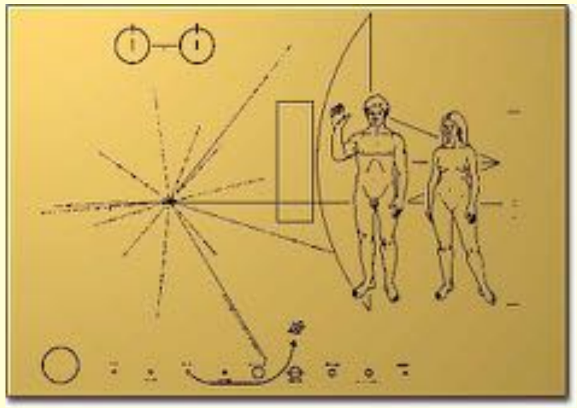




Consider this example. This was actually sent into space by NASA on the Pioneer probes to send a message to any aliens who might one day find the probes. Can you work out that these aliens were supposed to learn from this?

NASA’s attempt to tell aliens about us

What was the message?

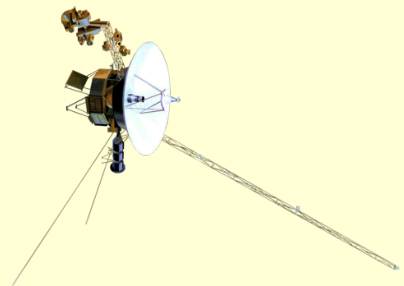


1972

“On the plaque a man and woman stand before an outline of the spacecraft. The man's hand is raised in a gesture of good will. The physical makeup of the man and woman were determined from results of a computerized analysis of the average person in our civilization.
The key to translating the plaque lies in understanding the breakdown of the most common element in the universe - hydrogen. This element is illustrated in the left-hand corner of the plaque in schematic form showing the hyperfine transition of neutral atomic hydrogen. Anyone from a scientifically educated civilization having enough knowledge of hydrogen would be able to translate the message. The plaque was designed by Dr. Carl Sagan and Dr. Frank Drake and drawn by Linda Salzman Sagan.”
http://www.nasa.gov/centers/ames/missions/archive/pioneer.html accessed 22nd November 2013

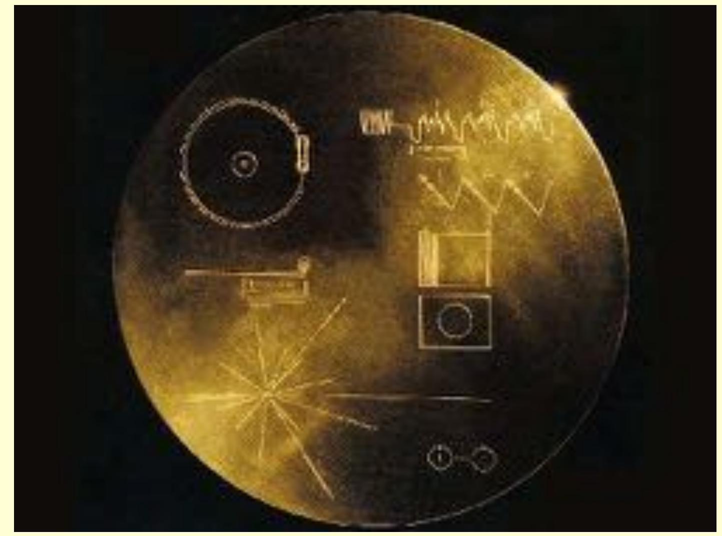
It is difficult to communicate with people who may share little of your cultural background.

…then they got ambitious



So what is that all about?

1977

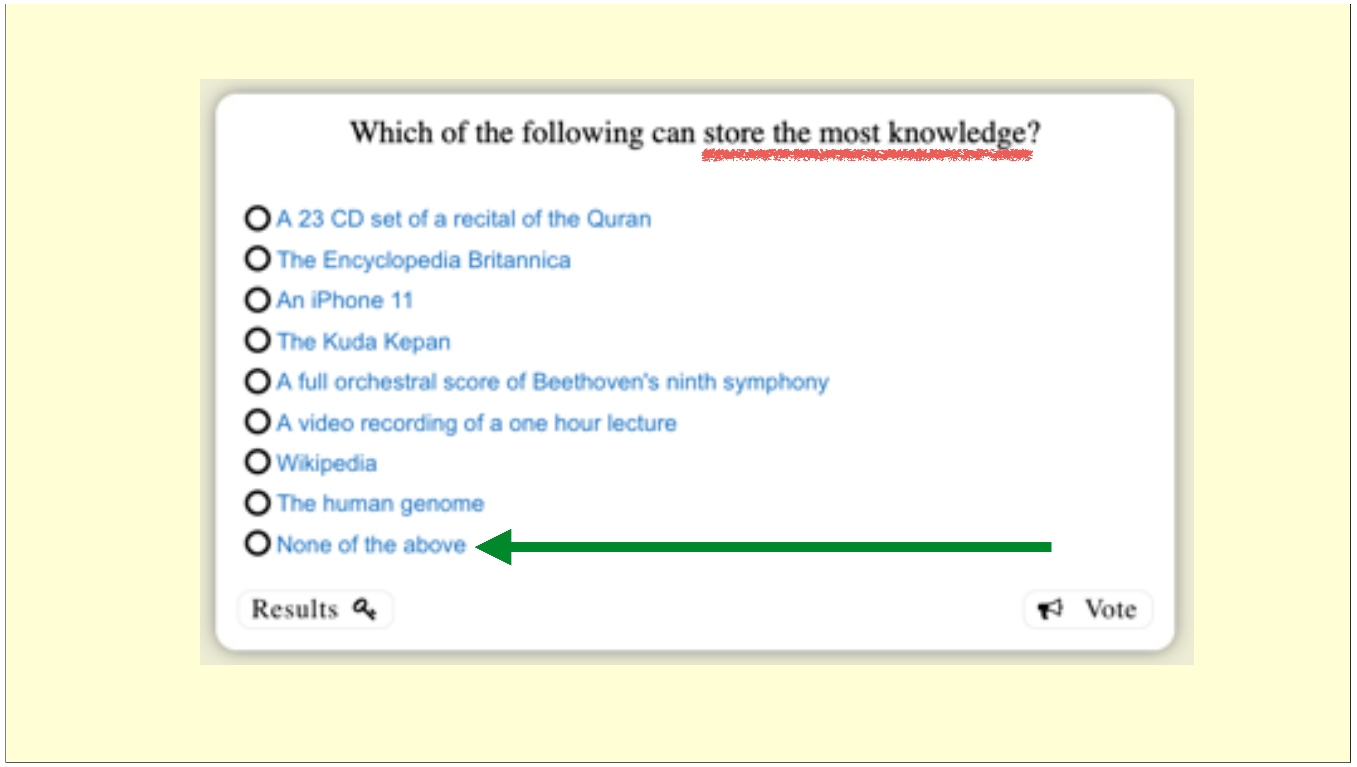


And then for the Voyager probes NASA sent this along. A different message:

Can you tell what this is all about?
[https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-learning-lecture-preview/ See ‘Can you read this message?’]

NASA sent a record into space, and the cover included the instructions for making a record player to convert the coded information into sound.

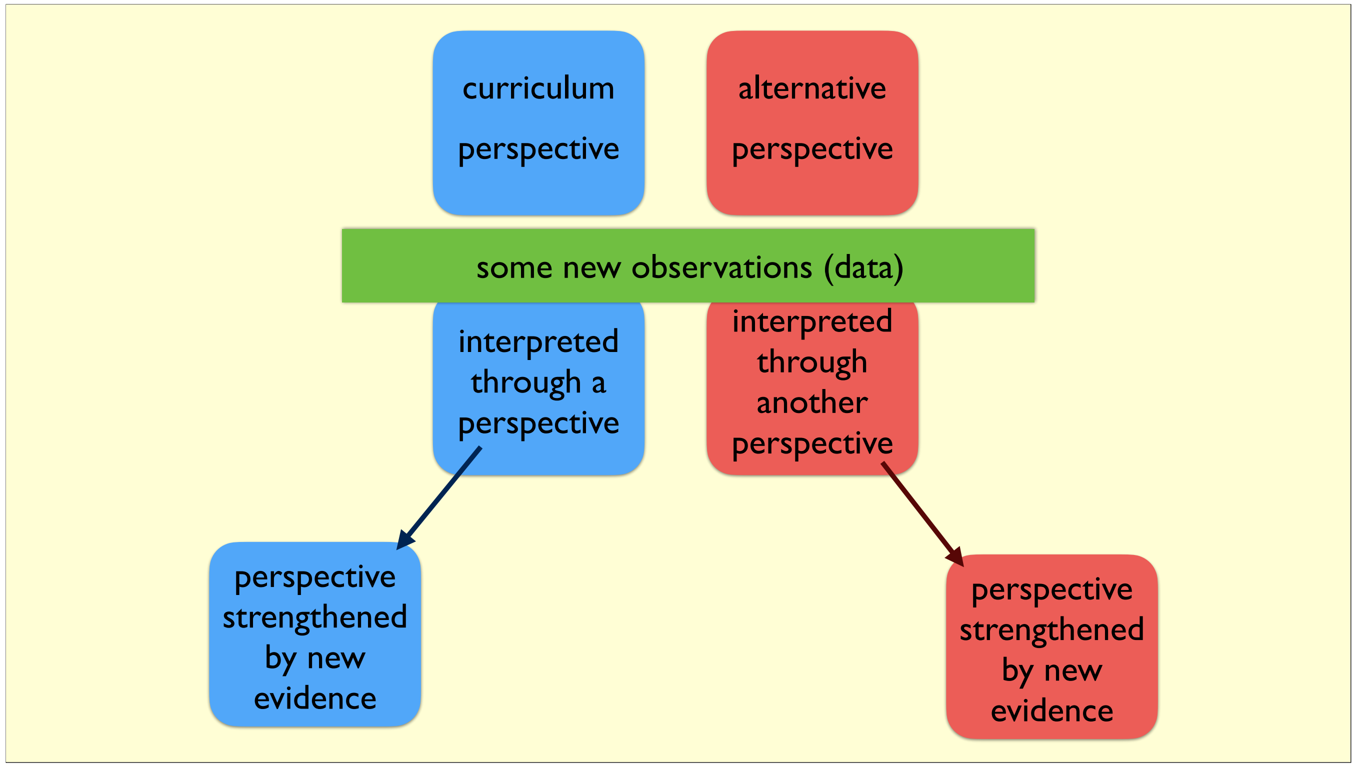
Did you earth people work that out? (If not, what chance have the aliens got?)



So, I would argue that it is not possible to store knowledge in books or computers or any other kind of device. Knowledge only exists where there is a knower.

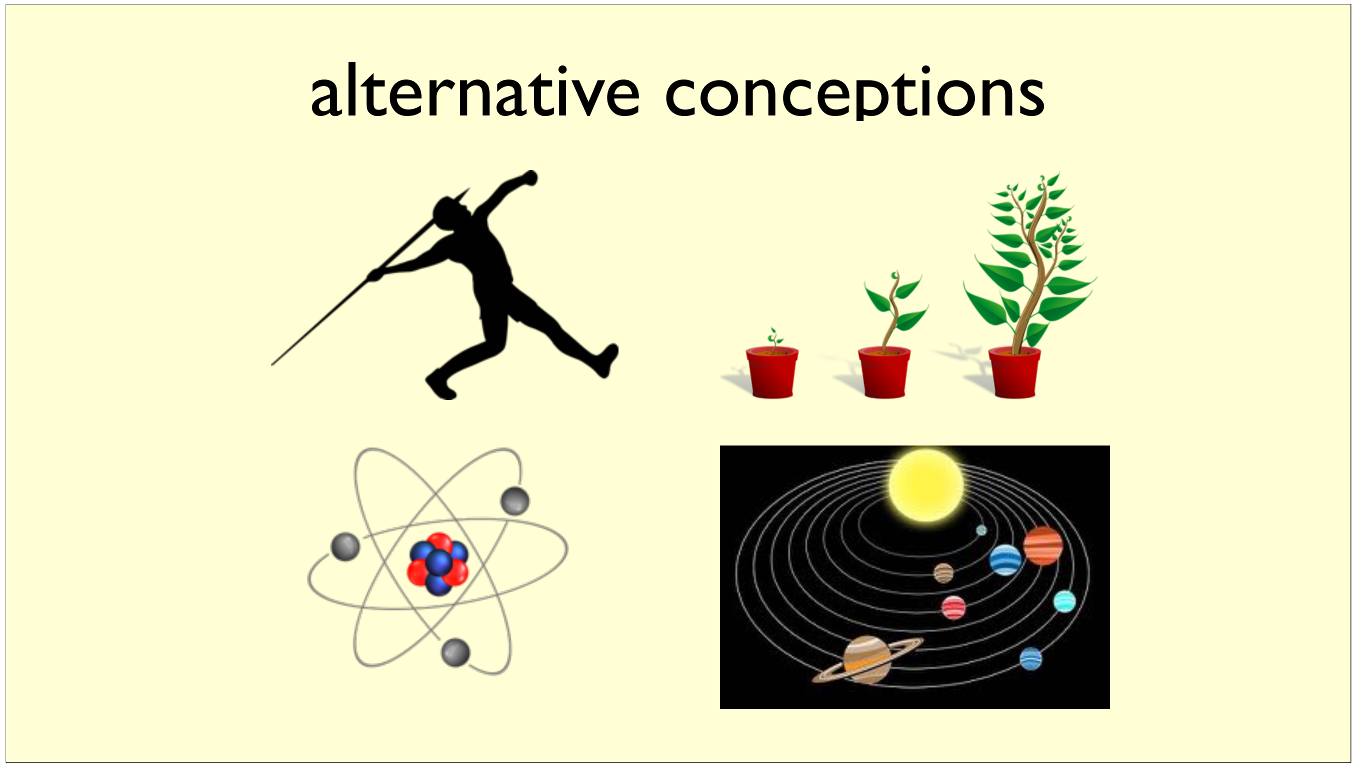
If you have knowledge you can try to communicate it to other directly, or indirectly, but you only represent the knowledge, and the representation needs to be interpreted if someone is to construct knowledge from it.

And as experienced teachers and most parents, indeed most human beings, know: the reconstruction process is not infallible. What is reconstructed is not always what was intended to be communicated.



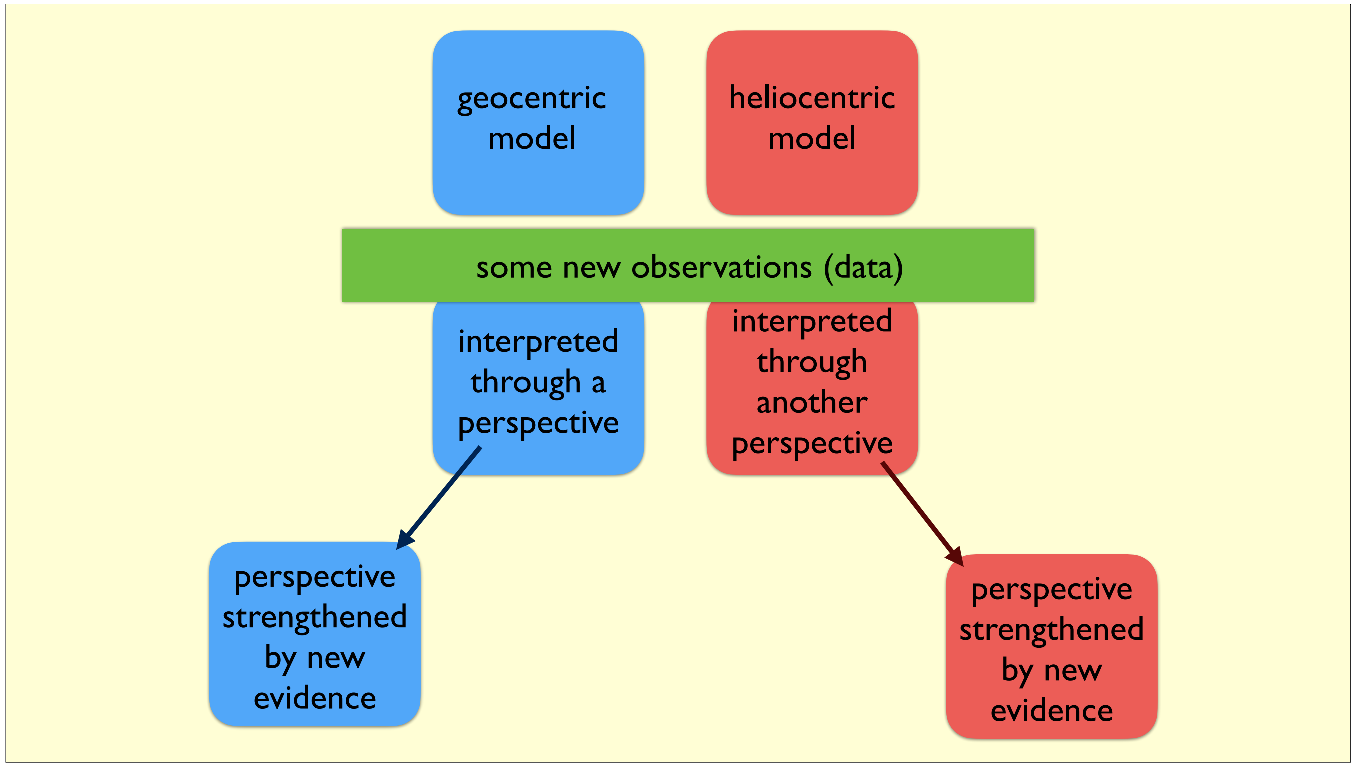
All of this is very relevant to teachers. If a person in a class has alternative ways of understanding a topic, they may well interpret teaching accordingly. So, if teachers are not aware of the issue, teaching that they might expect to challenge misconceptions can actually simply reinforce them.

What people hear is not always what is said to them. Teachers have to appreciate that learners can misconstrue what they are told. Perception is always based on a good deal of interpretation, and we can never assume our communication is clear and unambiguous. There are usually various ways of understanding any message.

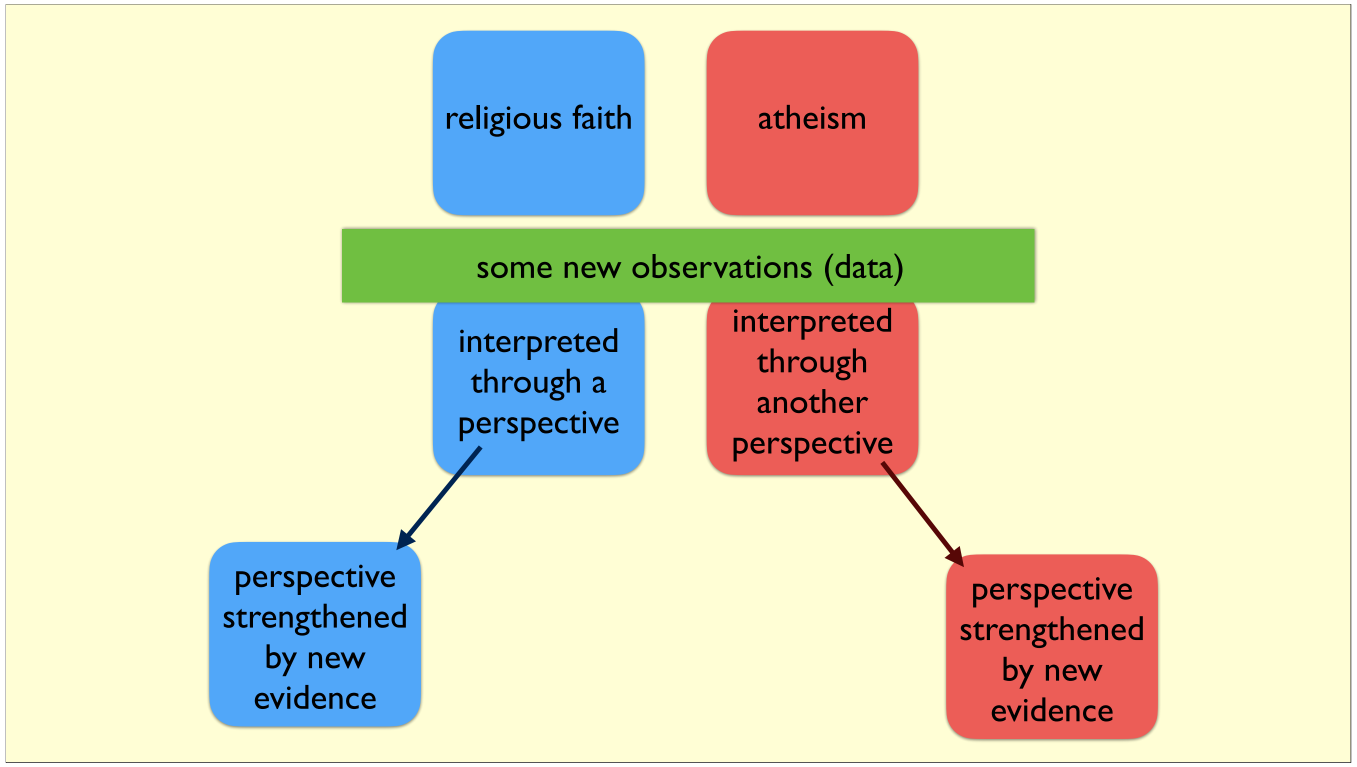


And if learners come to class with alternative conceptions they will often find ways to make sense of teaching accordingly, and go away even more convinced about their ideas.
[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/]

At least, unless teaching is informed by constructivist ideas.

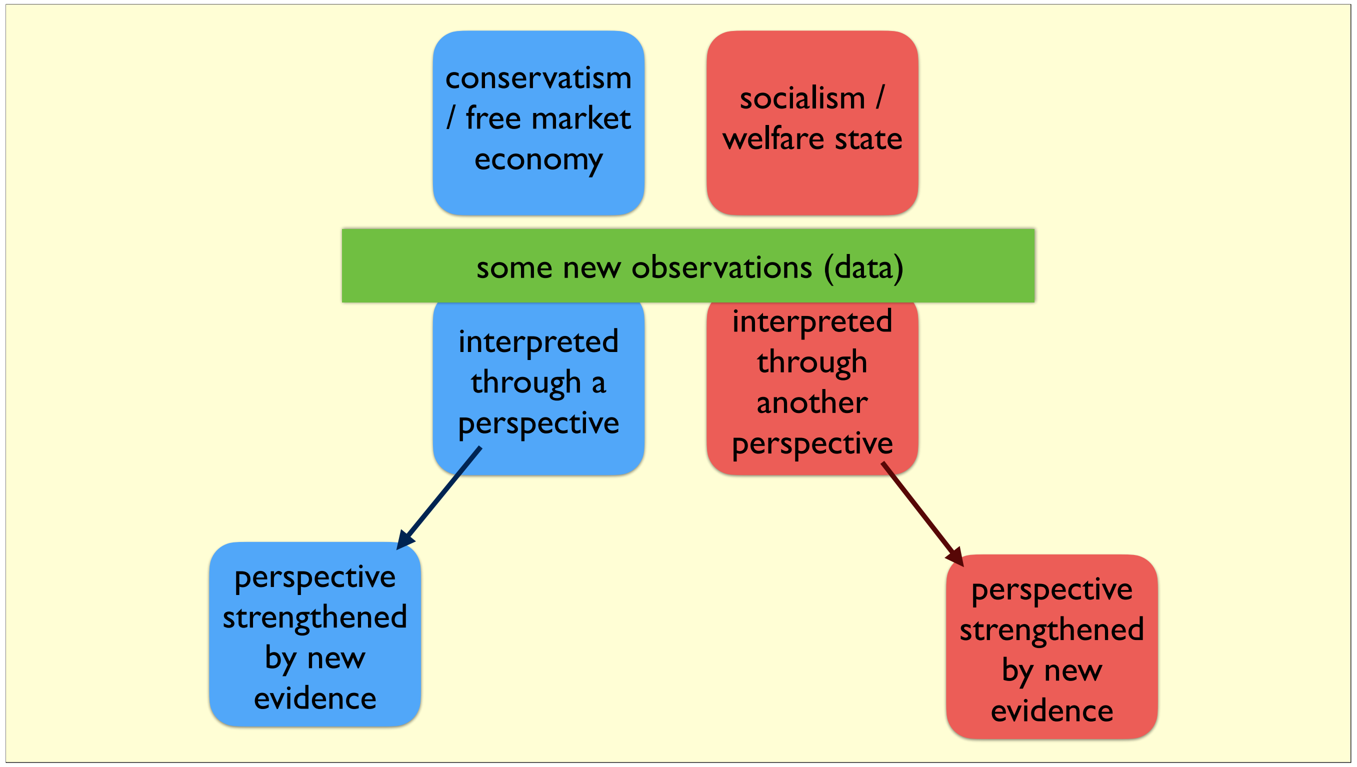


We find the same effect in academic life. Most major intellectual revolutions involve major changes in ways of thinking about the world, to new ways of thinking that seem obvious after the event - but often at the time it is not at all obvious to those holding the earlier view that it needs to change.

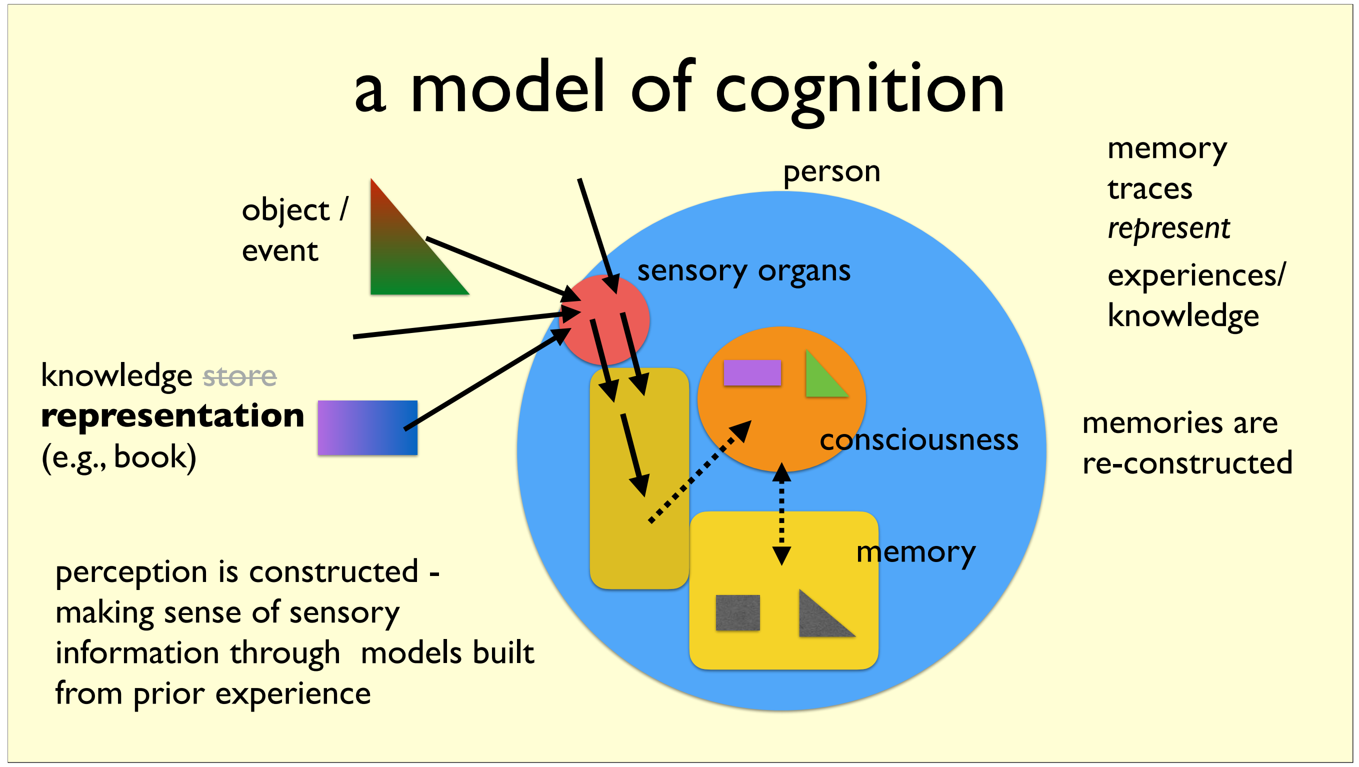


And we find much the same in all areas of life.

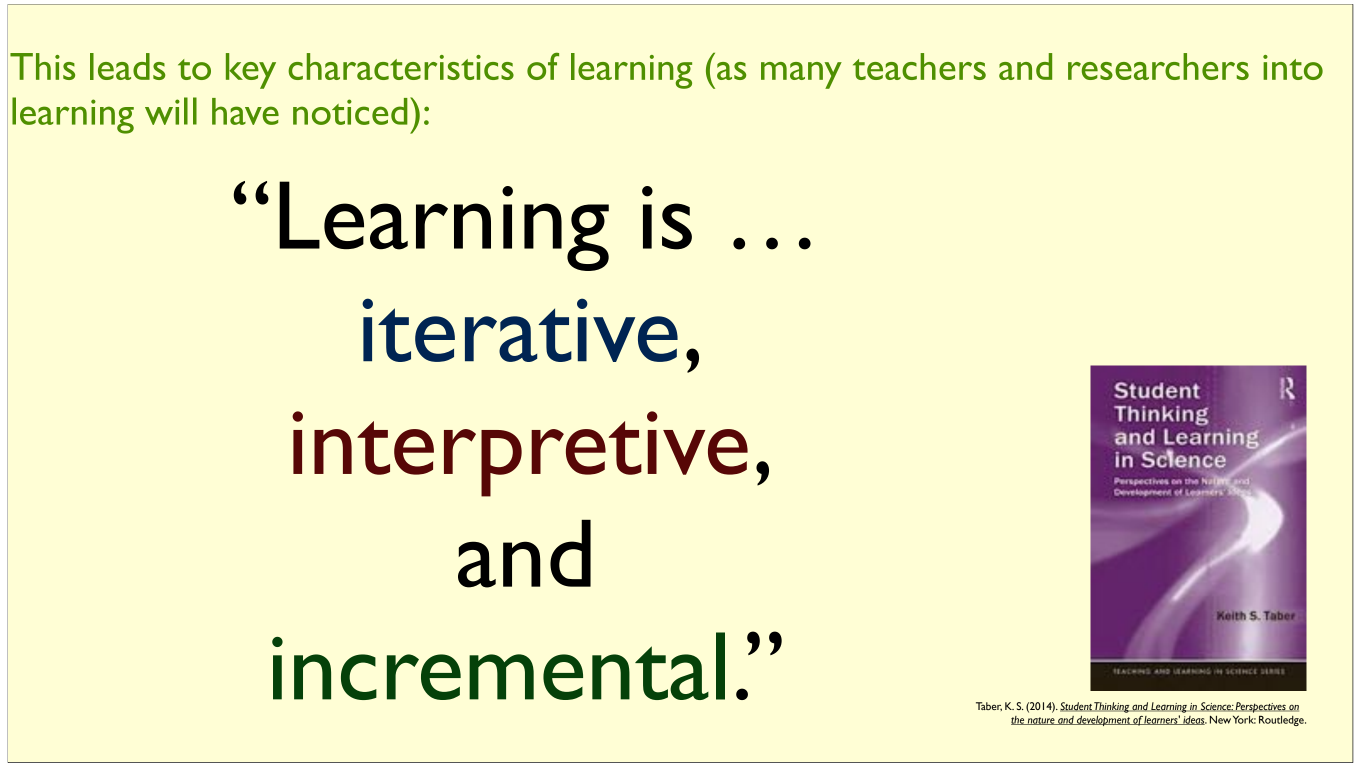
We talk across each other when we approach a discussion from drastically different interpretive frameworks.



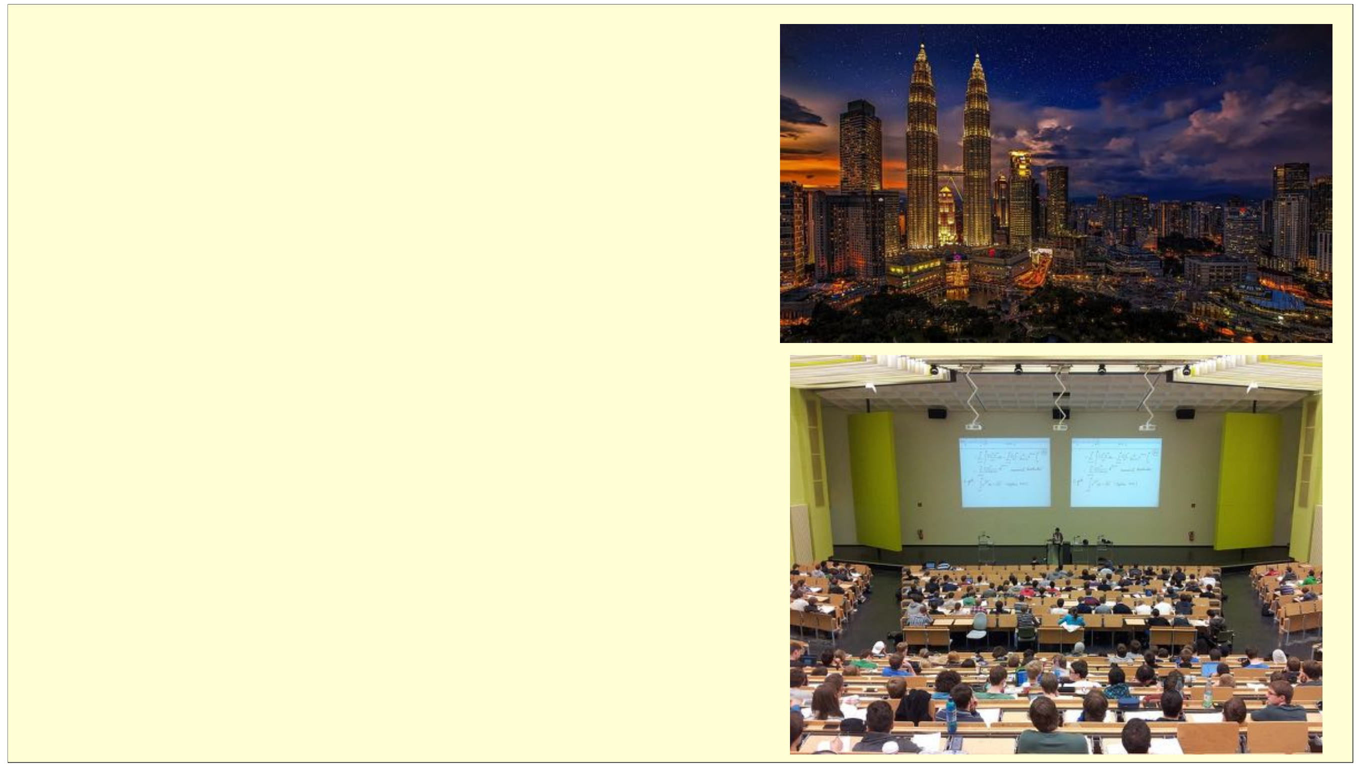
And there is a reason why you should not talk politics on polite social occasions.



So cognition is more complex that our naive everyday models suggest.
We construct our understanding of the world in perception, and we do so in ways biased by our expectations based on previous interpretations of experience which channel our current thinking. We learn how to see the world - we construct an internal mental model that seems to work most of the time. This allows us to cope in a complex world, but only if we tolerate misinterpretations. The cost of being able to construct knowledge, is that knowledge is never certain. The cost of being so good at making sense of experience, so good at finding ways to understand the world, is that we sometimes misunderstand.
Communication is never the sharing of understanding, but only the representations of one person's understanding in a public form that another person with the right interpretive resources can reconstruct.
Memory is not a store, but a way of representing experiences so we can later try and reconstruct them. Memory does not seem to have evolved to be accurate, but rather to offers us the best model of the world to guide action now.



In summary, this leads to learning being interpretive, incremental and so iterative. [https://science-education-research.com/publications/books/student-thinking-and-learning-in-science/]
This is the constructivist perspective on learning. We build models of the world and slowly modify them in response to evidence that we inevitably tend to interpret according to those very models. Perceptions is never neutral, as it is influenced by prior learning. Communication is always open to misinterpretation. External representations of knowledge, such as texts need to be interpreted. Memory is not a means of keeping past experiences in their original form, but a facility for using past experience to help shape our current ways of experiencing and acting in the world.

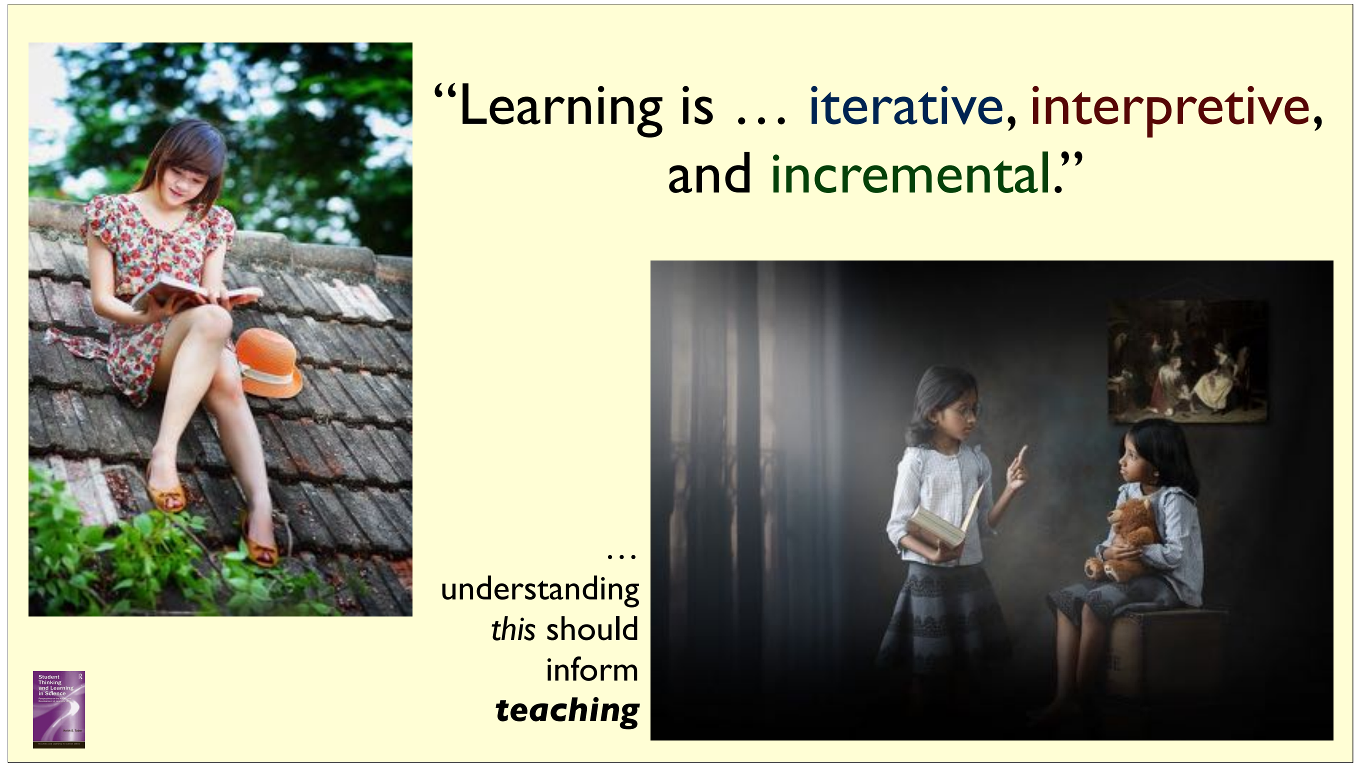


The biases in our cognitive systems that make human learning imperfect, and the resistance to recognising evidence that is contrary to well-committed beliefs, are sometimes unhelpful when living in the modern, fast-changing world. The tendency of young children to develop intuitive theories and alternative conceptions which will interfere with what they are later asked to learn in education, often makes school and college learning difficult.

But, of course, most of our ancestors had to survive in very harsh environments that were relative stable and where coming to terms with the basic nature of the world quickly was more important than having a fine grained and labile model. If they had been fine-tuned to live in the 21st Century, they would not have coped in their own context.

Our cognitive systems are inevitably biased and imperfect, but we should be grateful as this allows a hopeless new-born baby to bootstrap itself into someone able to make sense of, and act intelligently in, the world in just a few years. The biases and flaws in our cognition are the cost of achieving something that seems miraculous. We all have workable models of the world, including of other people, and indeed of ourselves, that allow us to be sentient, conscious, agents in the world. Those models are not perfect, but without them our experiences would be chaotic. And our models work a lot of the time, so isn't it better to live with a sometimes inaccurate and distorted representation of the world, rather than to remain like a newborn struggling to make sense?

If we developed more slowly, then we could likely have less error-prone learning - but who wants to only become an adult at fifty?



So, in many ways we should be grateful for the learning apparatus we have, even with its biases and imperfections. Nonetheless, for those of us in education, the constructive nature of learning presents challenges to both teachers and learners themselves, so the question becomes how we can best organise teaching and learning in the light of this perspective.

That is a very important topic, and one for another day.

Thank you

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