UNIVERSITY OF CAMBRIDGE

Seven slogans for constructivist teachers: *key ideas for teaching in accordance with learning theory*

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In my previous lecture I reviewed key ideas about the nature of learning that are fundamental to a constructivist perspective on learning. In that lecture it was suggested that our understanding of the nature of learning should inform the work of teachers, whether working in schools, universities or elsewhere.

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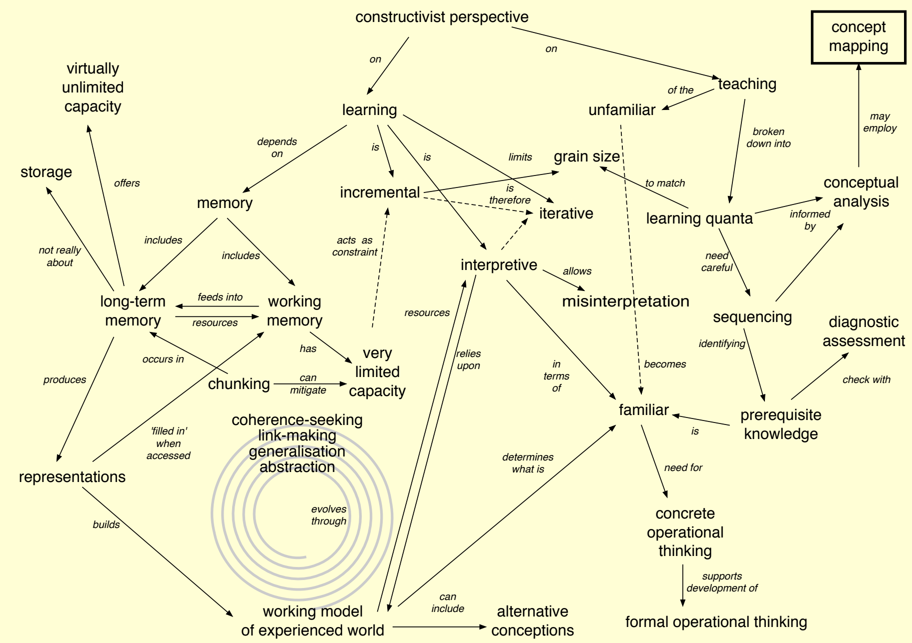
[https://science-education-research.com/about-keith/universiti-teknologi-malaysia/key-ideas-for-constructivist-teaching/]

Constructivism as a theory of learning should inform teaching



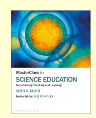


Image from K.S. Taber (2019) ***MasterClass in Science Education: Transforming teaching and learning***. London, Bloomsbury.

This lecture explores the nature of teaching that fits with constructivist learning theory. I have signified these key ideas in a series of slogans or mottoes. I find such slogans can be useful place-holders when thinking about teaching, and I hope others will also find them useful.

The seven slogans are:

- 'make the unfamiliar, familiar'
- 'share the learner's starting point'
- 'be a tour guide, not a road map'
- 'identify learning quanta at the learners' resolution'
- 'find the optimum level of simplification'
- 'mediate challenge with support'
- 'drip-feed reinforcement'

I hope that by the end of the lecture you will understand what I mean by these terms, how they relate to what we have found out about the nature of learning, and how they may be applied in teaching.

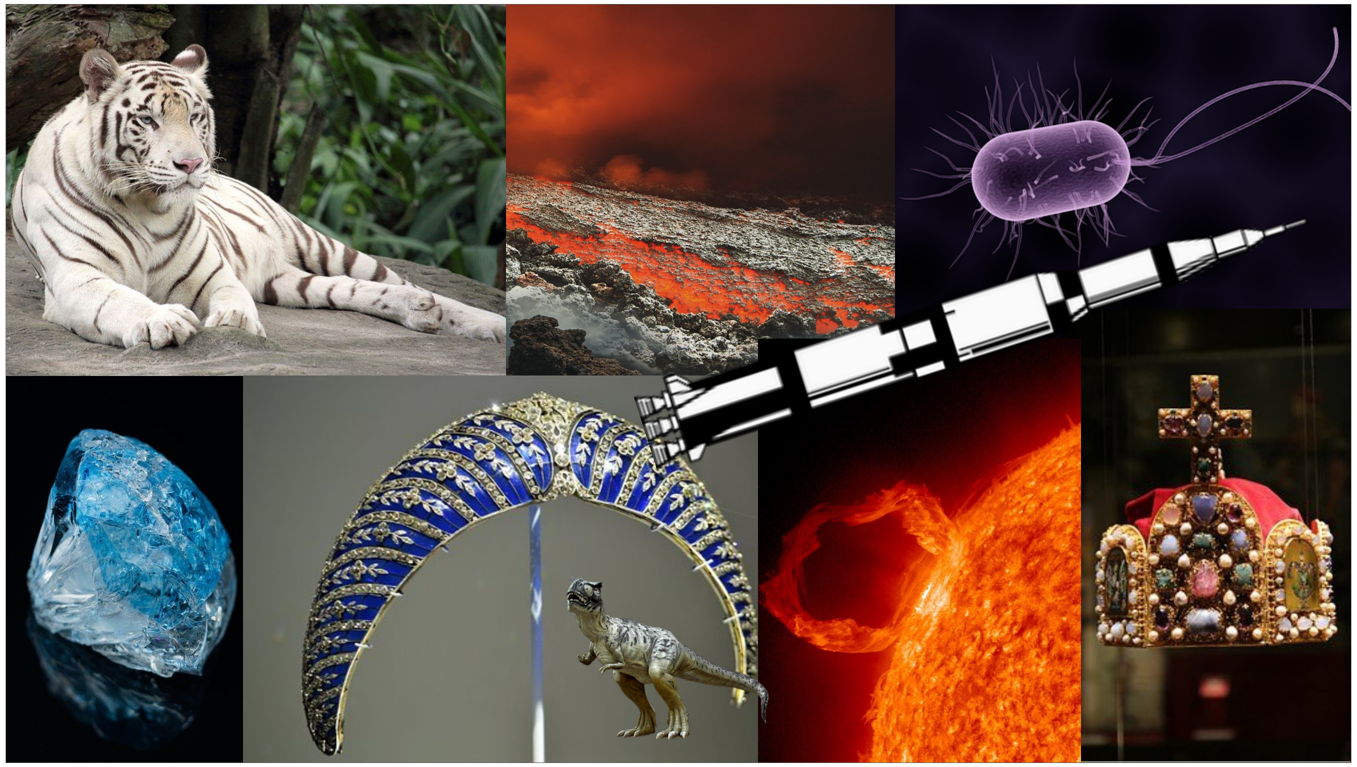
In an ideal teaching situation a teacher has plenty of time to prepare classes, to get to know students, and to work with them in a very interactive fashion. In reality, there may be limitations on actual practice. But if we keep in mind the ideal, and seek opportunities to work towards it, we are likely to be better teachers even if we never become perfect.

Indeed, knowing we are not yet perfect is probably a useful motivator to do better in future!

This is to my mind the essence of teaching.

When learning occurs, something that was not previously familiar has become familiar. Human beings naturally learn through their experiences of the world - they learn that dropped glasses often shatter; or that too many cakes and biscuits may lead to a queasy feeling.

In education, however, we are generally involved in teaching things that are unlikely to be learned spontaneously, because they are unlikely to be familiar from everyday experience.



Sometimes, things that are unfamiliar from everyday experience are not familiar because they are rare, or dangerous, or on an inaccessible scale

Sometimes they are just specialised. So, for example, laboratory apparatus is not usually met outside of laboratories.

Sometimes what is unfamiliar is readily available in the culture, but may not seem relevant to students unless they are nudged towards it.

I am thinking here of what might be termed 'high culture', where students from different social backgrounds may have different social capital in terms of what is available, and discussed, in the home.

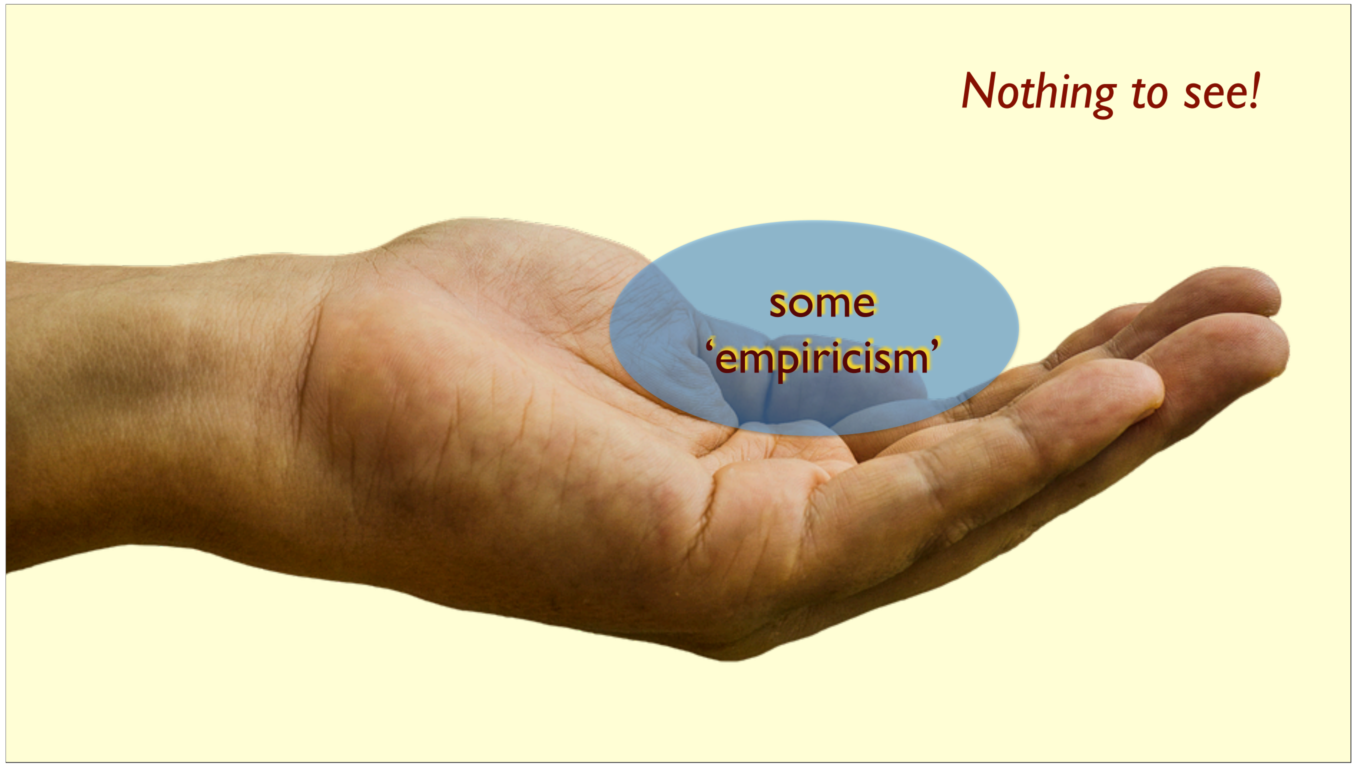
Of course, there are value judgments to be made about which forms of culture are worth sharing - after all picking pockets and taking narcotics are undoubtedly aspects of culture in many societies, but that does not mean we wish to induct young people into these behaviours.

However, often in formal education things are unfamiliar for a different reason. Things that we are asked to teach about are often unfamiliar because they do not really exist. I mean they are abstractions. They are not things that a person will find in the street, pick up, handle, prod, or test by dropping on a hard surface.

A good deal of school education, and higher education, is not about teaching about objects or events as such, but as generalisations, as concepts.

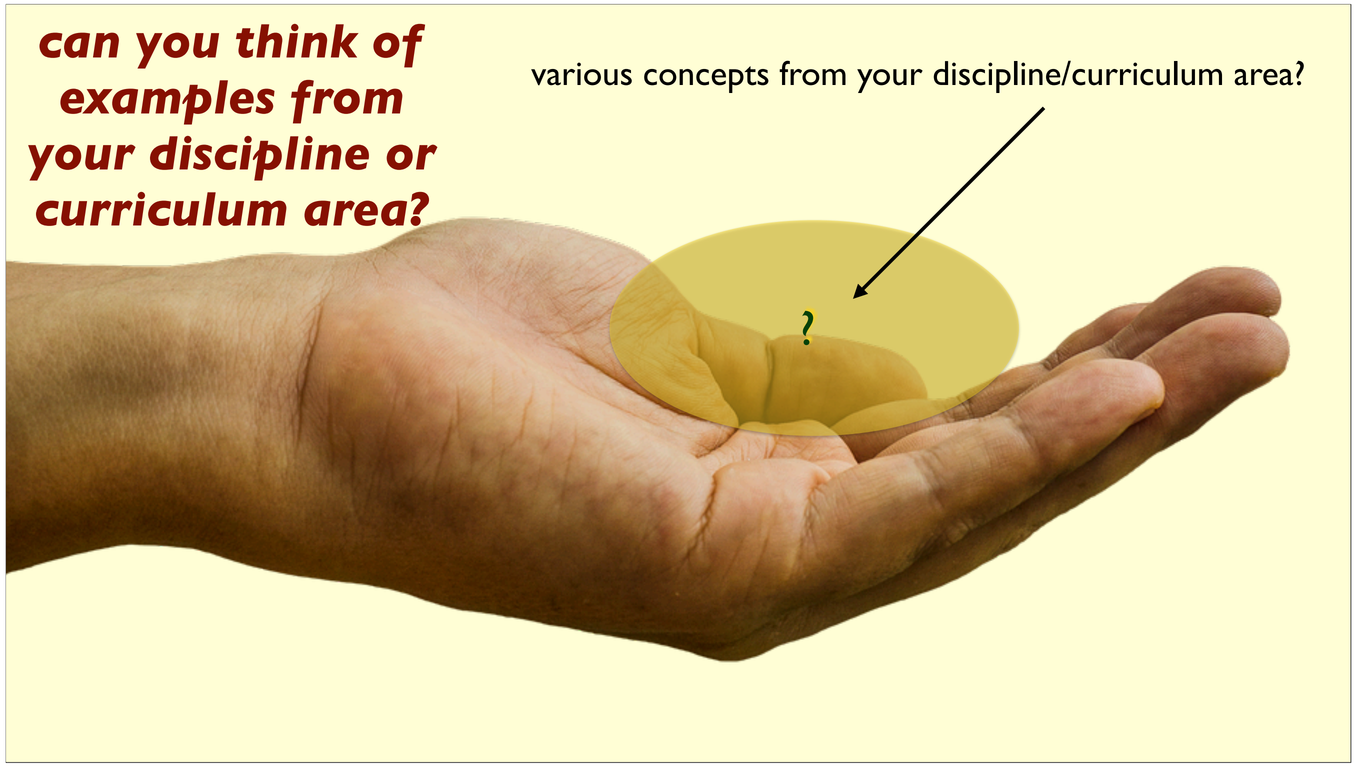
There is no such 'thing' as price elasticity of demand, for example, that you can take out of your pocket to show anyone. The concept refers to an abstracted feature of a complex system.

So, the teacher may have the task of making sure students recognise price elasticity of demand, or an electric field, or a molecular orbital, when they see one: but first they have to learn to see these things, as they do not exist as directly observable phenomena in the world so we might say 'there is nothing to see'.


Nothing to see!
some
'empiricism'

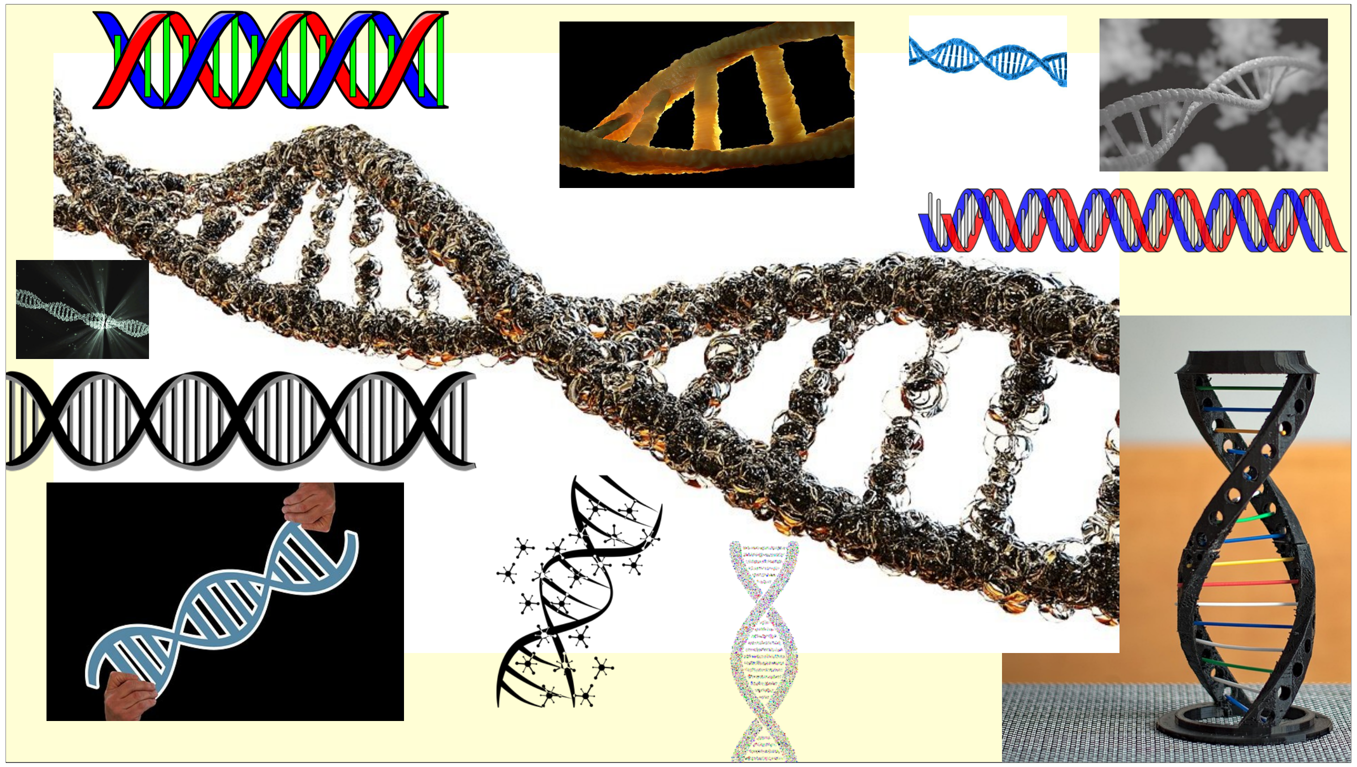
Nothing to see!


Nothing to see!
some
‘professionalism’


can you think of examples from your discipline or curriculum area?
various concepts from your discipline/curriculum area?
?

Perhaps it seems contrary to suggest that people can learn to see things that do not really exist. It might be suggested that this is a sloppy way of saying that people learn to, after the event, conceptualise phenomena in terms of these abstract ideas. But actually with sufficient familiarity you can learn to perceive these things, just as when you see a bicycle you do not need to do a deliberate analysis to identify that is what you are seeing - this has become automatic.

I do not know what this picture actually shows, but I immediately know what is meant to be represented, and I ‘see’ DNA.



Indeed, I can immediately see DNA in a range of actually quite different representations.

Something similar happens in all of us with learning to hear language. We start just hearing sounds, but as adults we automatically hear words, usually without any deliberate effort.

A new born baby cannot initially see a bicycle or a coconut or an elephant, but with sufficient familiarity we all learn to interpret sensory data so we do come to see such things.
The same cognitive processes can help us learn to see electric fields or inflation or corruption.

But this takes some work.

person
politician
prisoner
president
man
Nelson
husband
ex-husband
father
grandfather
Father of the Nation

The same entity may have several different identities according to context

If a child is taken to a forest, and a ‘tree’ is pointed out to her, how does she know if the signifier ‘tree’ means the single plant, or the collective, or the tree with its soil, or just the trunk, or just the bark, or that branch; and does tree refer to any of these big plants, or just one type, or just this one particular example?

If you know what ‘coffee’ refers to then it is obvious what is being pointed to here: but otherwise just pointing is not enough as there are a range of potential referents,

…including the finger itself.
So, if you are charged with teaching learners what is meant by a conical flask or a flat-bottomed flask it is wise to do more than just point at one whilst giving its name.

However, if you are charged with teaching learners what is meant by the Enlightenment, or by a hybrid atomic orbital, or moment of inertia, or a monopoly, you cannot simply point to one.

we teach about ‘things’ that do not actually exist

- price elasticity of demand
- revolution
- the (European) Renaissance
- democracy
- infinity
- hysteresis
- romanticism

…

- empiricism
- resonance
- inflation
- social capital
- electron spin
- ideal gases
- Raoult’s law

…

that is they are abstract generalisations about relationships etc.,

Here are some examples of things you cannot teach by having learners pass them around the class.

You cannot readily teach such things by ostention, by naming and pointing.

we teach about 'things' that do not actually exist

- price elasticity of demand
- revolution
- the (European) Renaissance
- democracy
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- romanticism

…

can you think of examples from your discipline / curriculum area?

- empiricism
- resonance
- inflation
- social capital
- electron spin
- ideal gases
- Raoult's law

…

that is they are abstract generalisations about relationships etc.,

definition example

An element is a chemical substance that cannot be broken down not anything simpler by chemical means

An element is a chemical substance that is made up from one kind of atom

One way we can teach about such intangibles is through definitions - careful logical delineations of these concepts.

definition example

An element is a chemical substance that cannot be broken down not anything simpler by chemical means

How can I tell what is simpler?

What counts as 'chemical' means?

(Is there a danger of tautology in answering these questions?)

But I cannot see, let alone sort, the atoms?

But only if isotopes are treated as ***the same type*** *of atom (for this purpose)?*

An element is a chemical substance that is made up from one kind of atom

Yet, in practice, a definition is often only helpful ***after*** someone has acquired the concept.

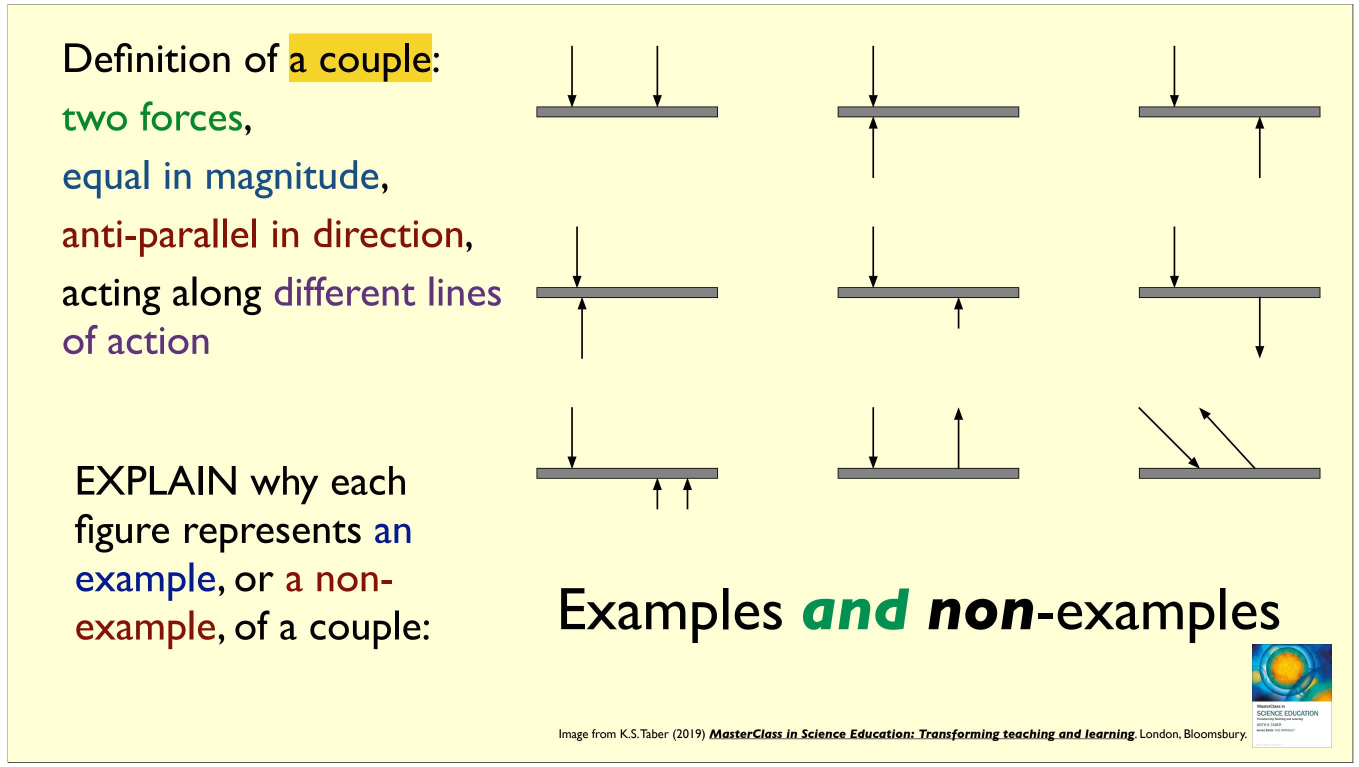
Definitions are important to the expert community, but of limited value to a novice.

When we do offer definitions we are always depending upon the learner's existing concepts. We always need to build with the conceptual 'bricks' learners have available.

Can you think of examples of definitions of key terms that initially make little sense to novices in your discipline or curriculum area?

An element is a chemical substance that cannot be broken down not anything simpler by chemical means

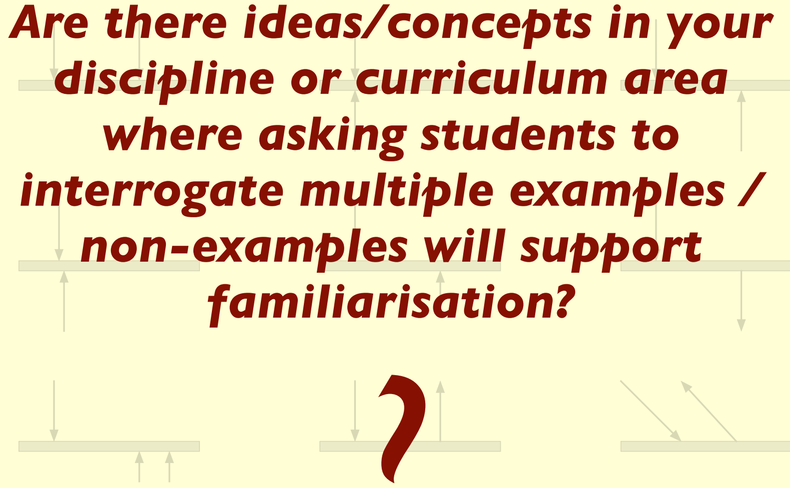
An element is a chemical substance that is made up from one kind of atom



Here is a concept with a multi-part definition, where we have to work with abstract representations. Learners can be asked to identify examples and non examples, and also to explain their assignment in each case.

Definition of…

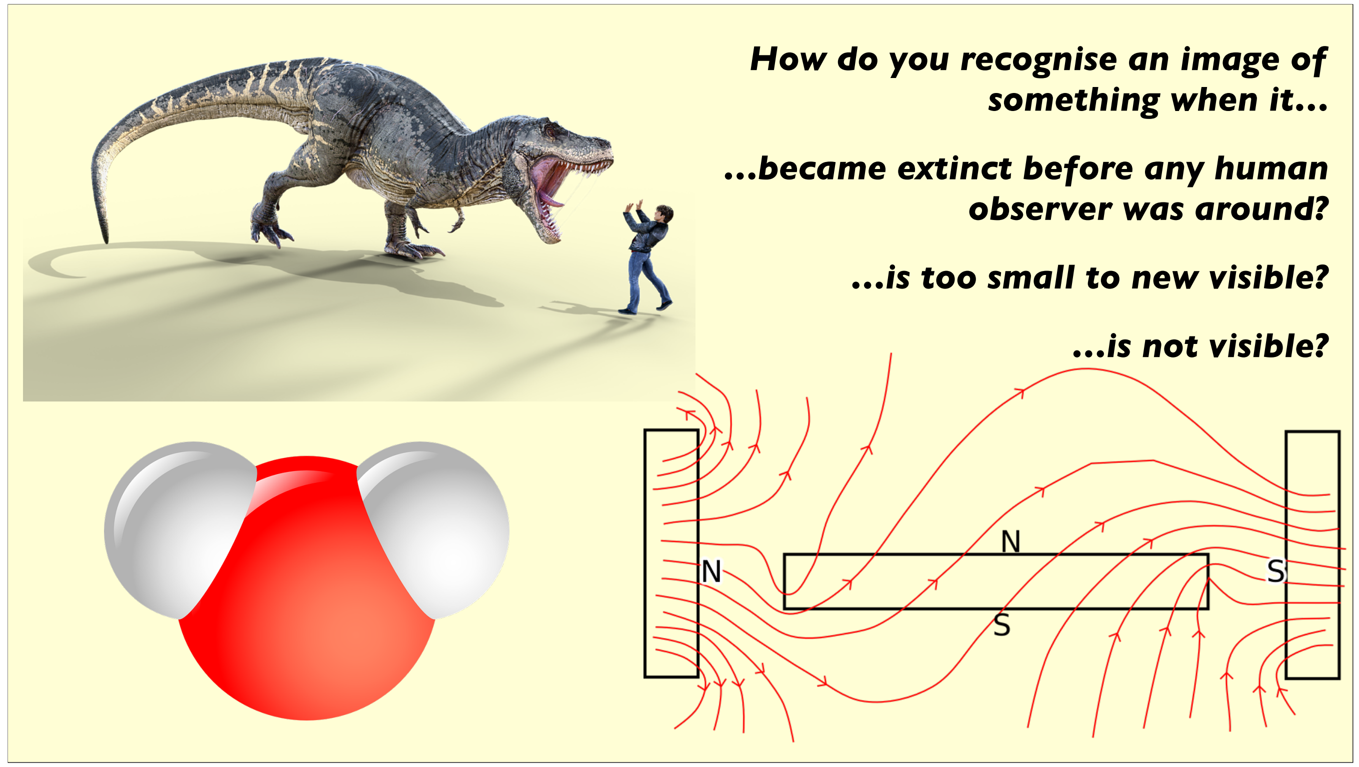
EXPLAIN why each figure represents an example, or a non-example, of…



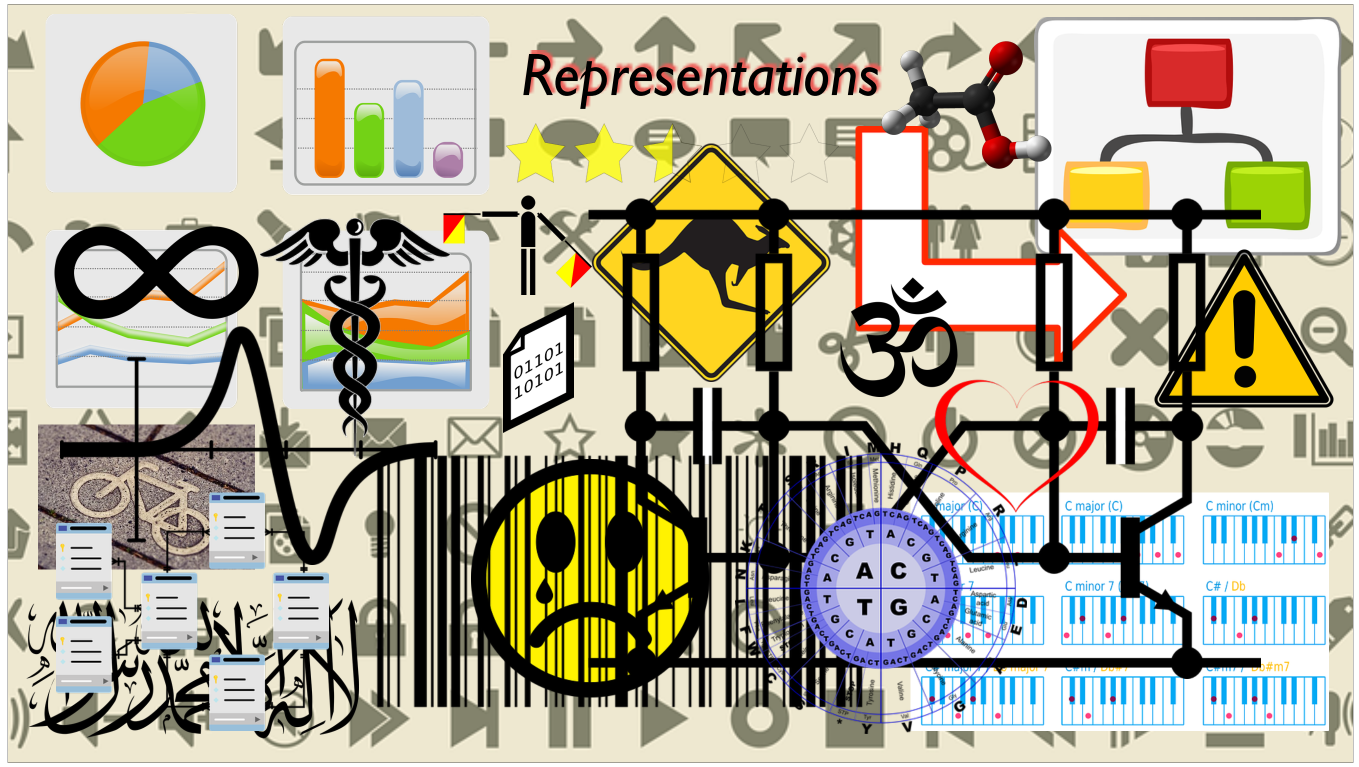
Are there ideas/concepts in your discipline or curriculum area where asking students to interrogate multiple examples / non-examples will support familiarisation?

?

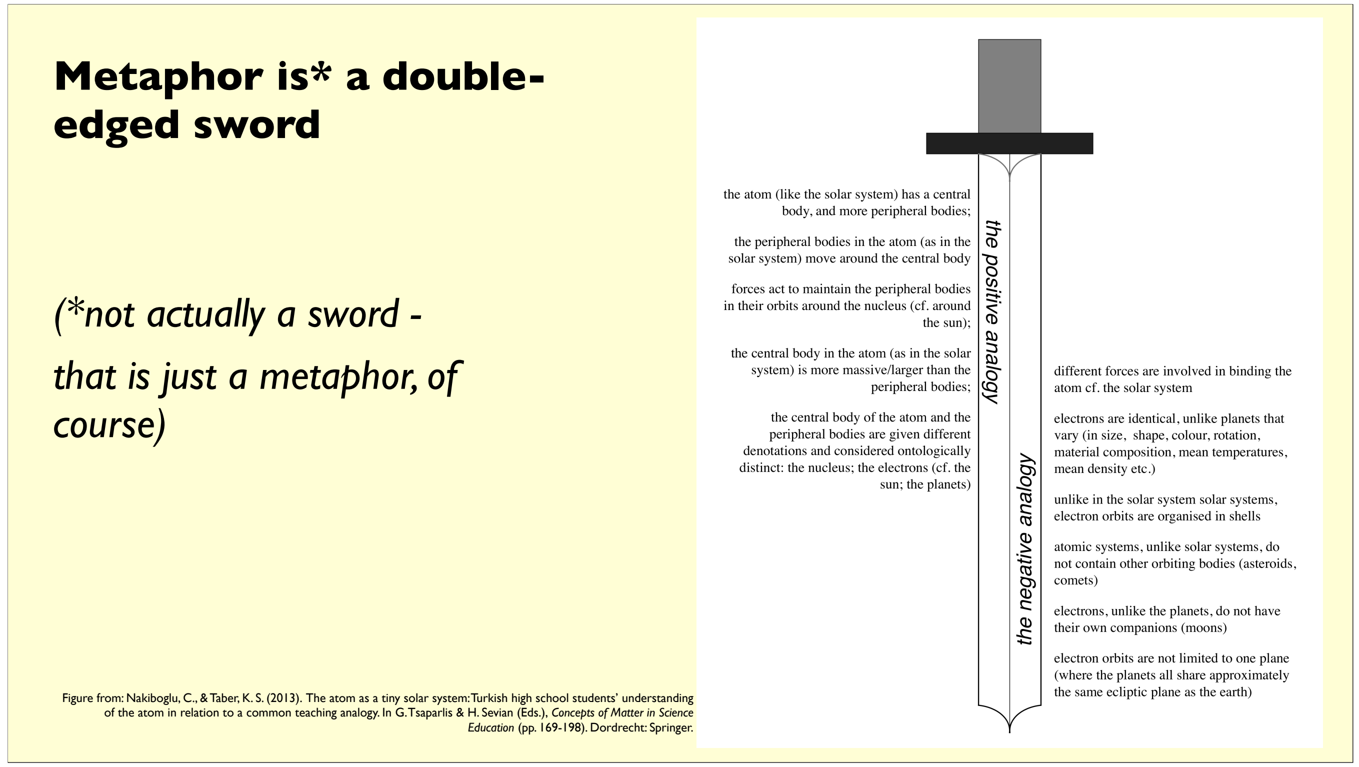
Examples ***and non***-examples



So, we make the unfamiliar familiar through representations, such as models, and through identifying similarities with what is already familiar to the learner. I expect everyone at this lecture knows what a T. Rex looks like, and you can probably form a mental image of a water molecule, or of a magnetic field, even though none of you have ever seen a living T. Rex; a water molecule is too small to be seen; and a magnetic field is not visible.



Teachers will be fluent in the use of the representation. However we have to remember that students need to learn about the form of representation itself, and become comfortable with it, before they can adopt it as part of their reservoir of interpretative resources.



We use verbal models too, in the forms of metaphor, simile, and analogy, as well as narrative, and sometimes anthropomorphism. You may notice I use a range of metaphors, analogies and images in this lecture.

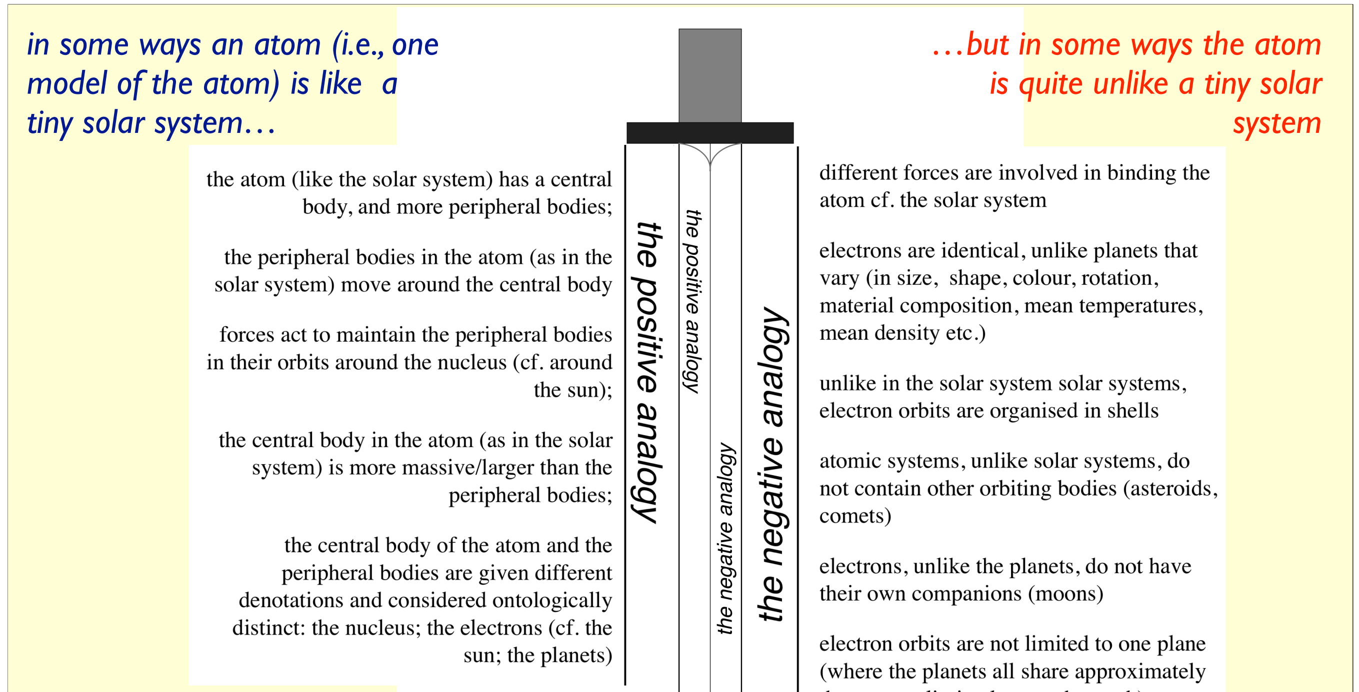


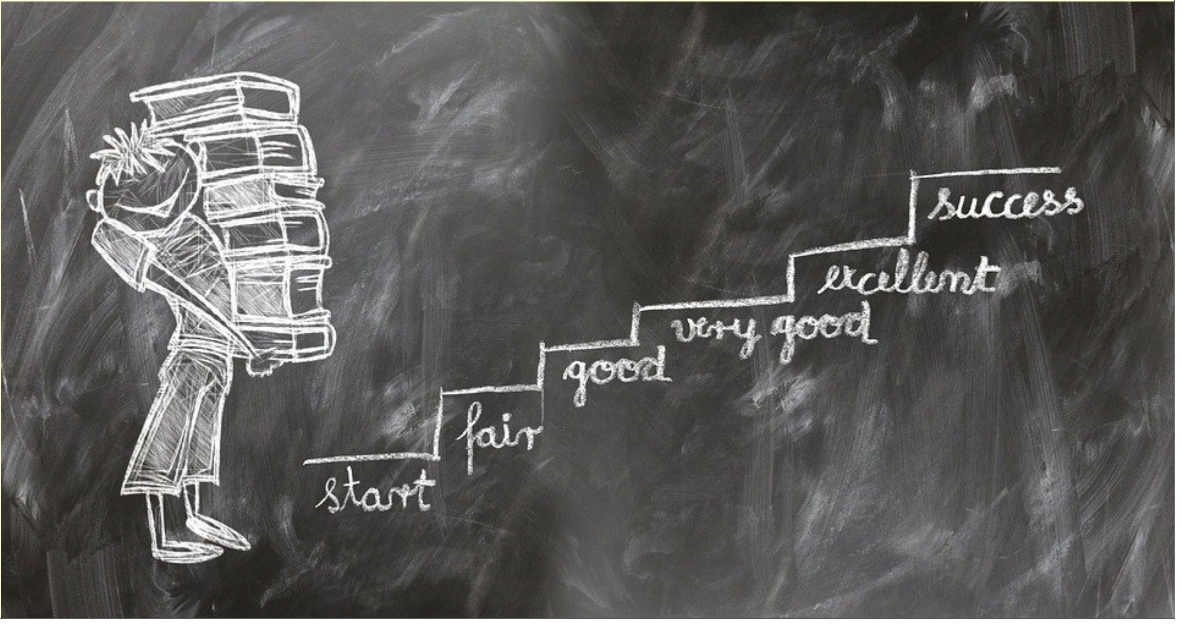
Figure from: Nakiboglu, C., & Taber, K. S. (2013). The atom as a tiny solar system: Turkish high school students' understanding of the atom in relation to a common teaching analogy. In G. Tsaparlis & H. Sevian (Eds.), *Concepts of Matter in Science Education* (pp. 169-198). Dordrecht: Springer.

We should be explicit with our students regarding the limitation of these devices. Even if there is a sense in which a nucleus is like the brains of a cell, or an atom is like a tiny planetary system, there are also many differences.

These metaphors and similes, and models and analogies and all the rest are very useful ways of making the unfamiliar familiar - but should be seen as a kind of scaffolding, a temporary structure that will be discarded once what was unfamiliar has become familiar.

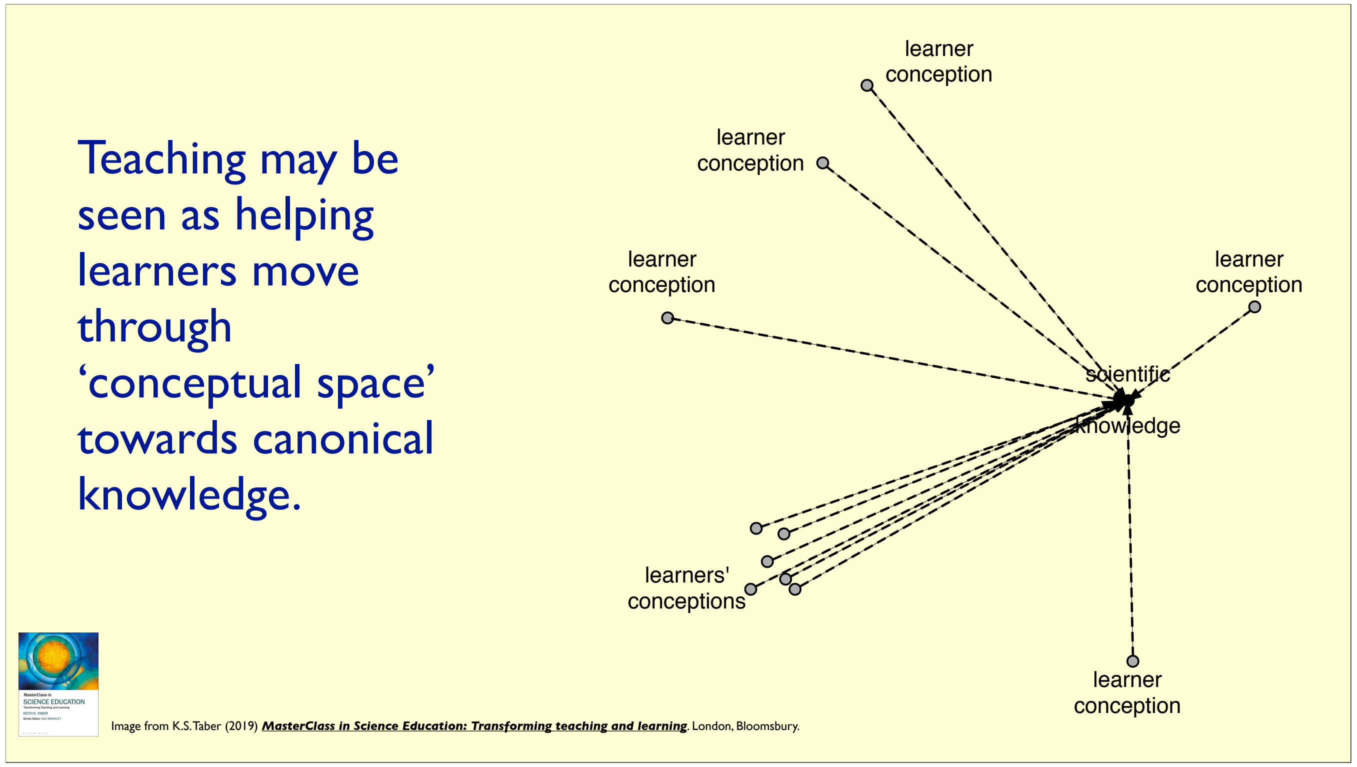
We look for ***anchors*** in existing experience and ***hand-holds*** in which to grasp new territory.

Share the learner's starting point



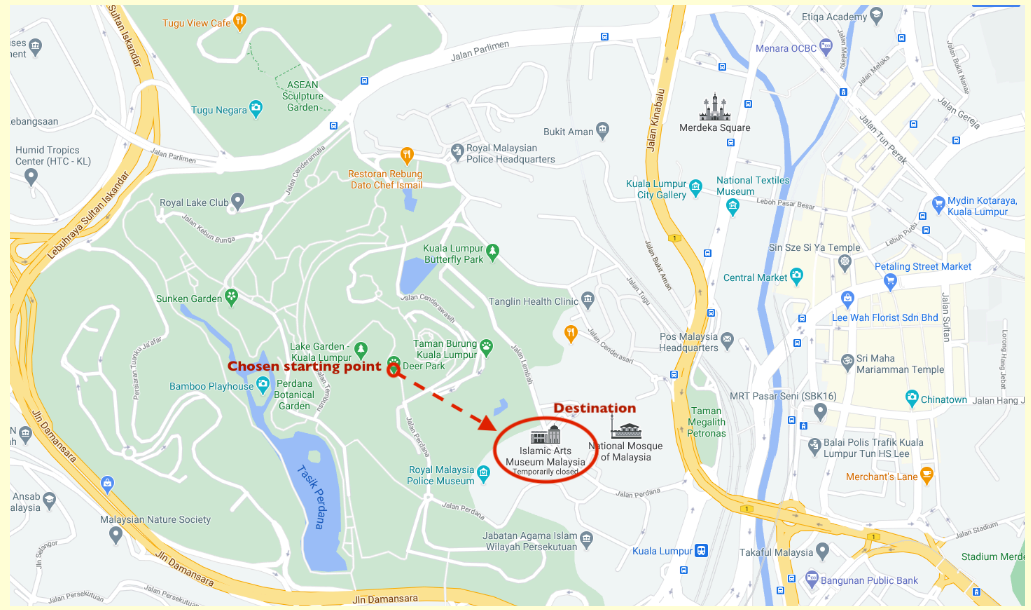
Moving on, in more ways than one, I am going to adopt a metaphor of my own.

Conceptual learning is a journey.



Or, at least, one can consider conceptual learning as a kind of journey, but not through the phenomenal world we experience as such, but through the world of ideas. The teacher seeks to move the learner through what might be termed 'concept-space'.

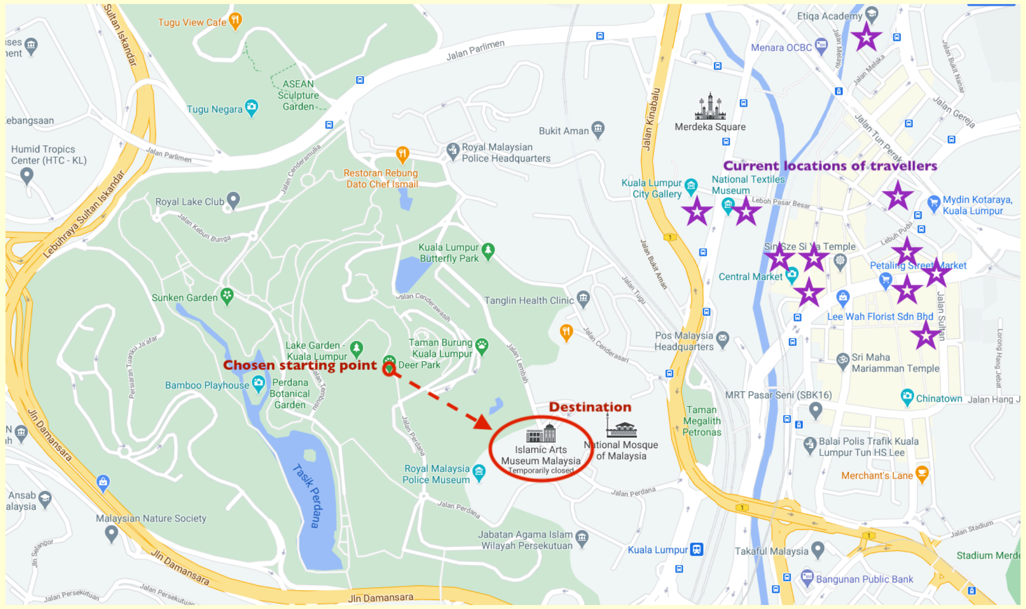
choosing a setting-off point…



Now unfortunately education has commonly been designed backwards. In most formal educational systems, there is a destination set out for the journey. The curriculum tells the teacher where the learners need to get to by the end of a semester, or by the end of a grade level, or by the end of a programme of study. The teacher has limited class time, so the teacher feels she cannot start too far from the next specified destination.

Which is fine of course, as long as the learners are near enough to where the teacher feels she needs to start.

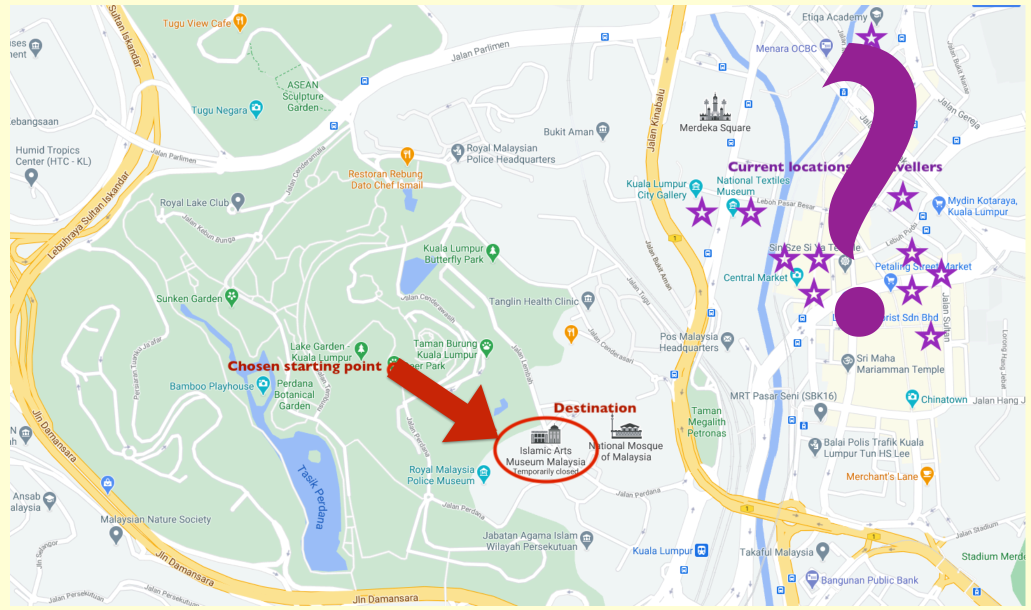
…without taking into account your current location



In practice this is often not the case. So some logic has to be applied.

If the learners are not where we would hope they would be, or where the curriculum documents suggest they should be, we have two options.

…without taking into account your current location

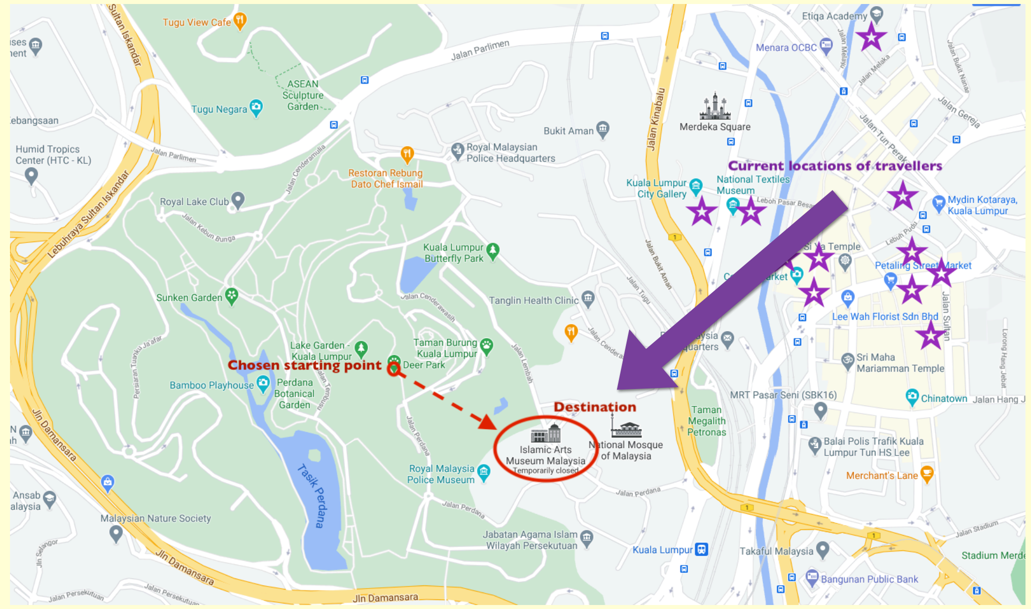


Option one is to ignore this, and carry on regardless.

After all, you are supposed to be teaching grade 10 students or second year undergraduates or whatever, and it is not your fault if these grade 10 students or second year undergraduates are not where they are expected to be in concept-space. The best thing to do is to teach as if they are, and finish the assigned curriculum.

Most of the learners are very unlikely to reach the expected destination in this approach, but you are teaching what you are expected to teach.
You cannot be blamed as you have taught the course materials, even if you have perhaps not really taught the students very much.

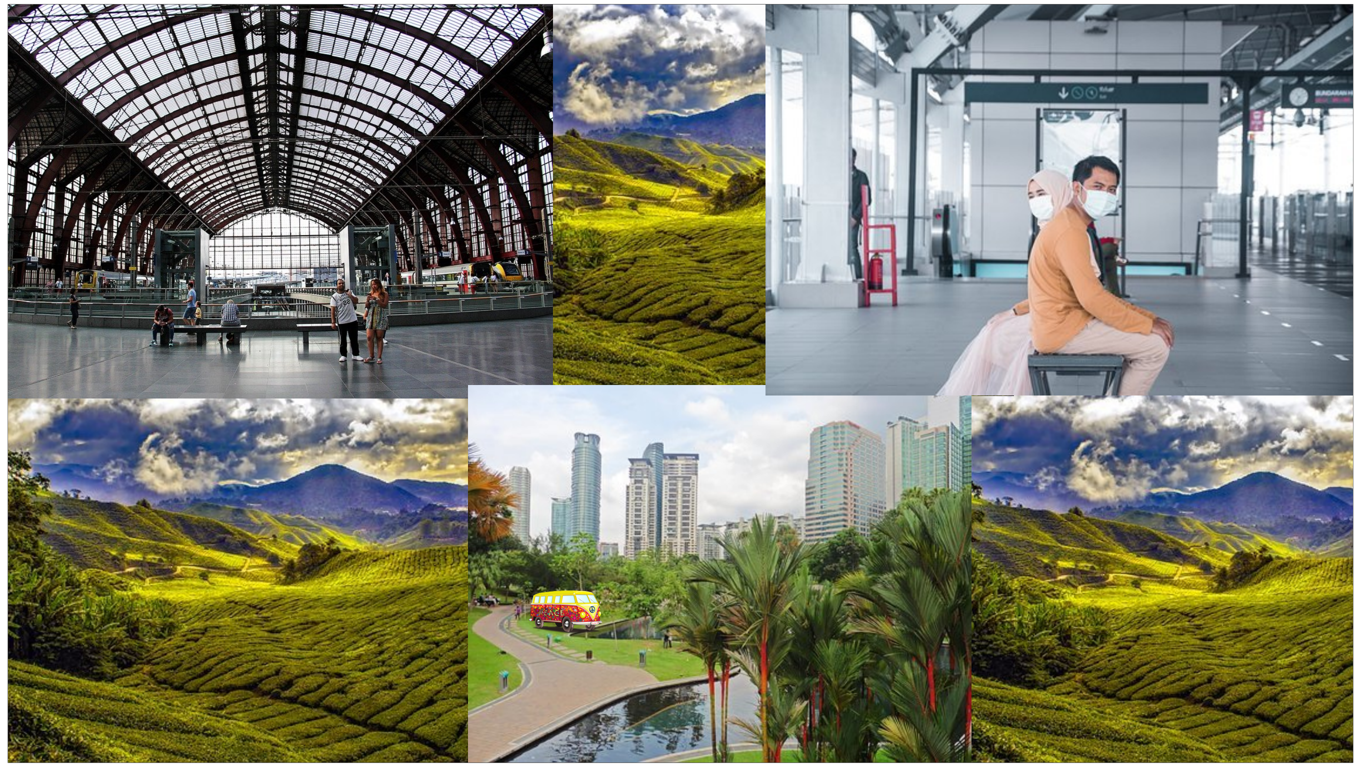
…without taking into account your current location



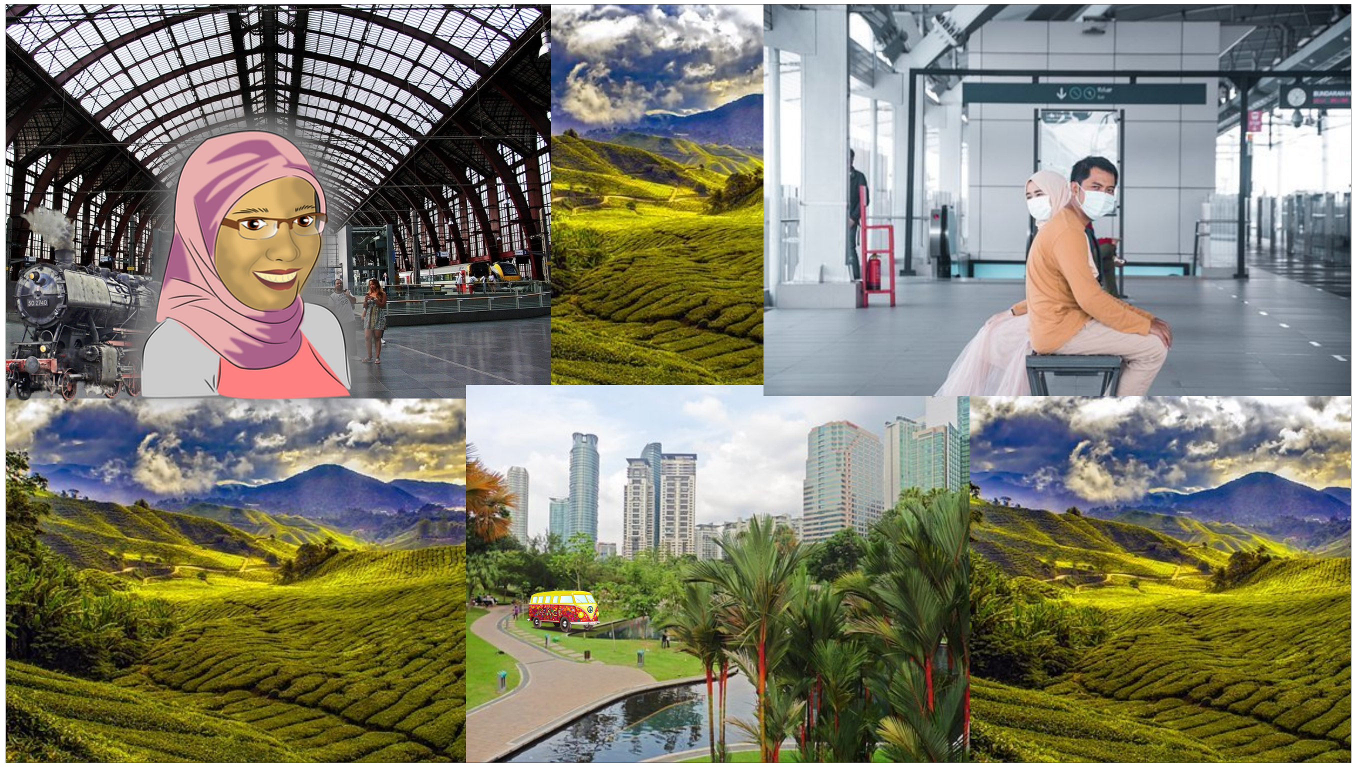
The other approach is to find out where the learners are and start teaching from their starting points, and then move them on as far towards the destination as you can, even if it seems very unlikely you can get them all the way to the intended destination from there in the time available.

Neither of these strategies are likely to allow the students to all perform excellently in an externally imposed final examination matched to the curriculum, so the difference here is how you see the role of the teacher. If the teacher's job is to teach the curriculum, then the first approach makes sense. If the teacher's job is actually to teach students, then the second approach makes more sense.

My notion of teaching as action intended to bring about learning better fits this second approach, where some useful learning is more likely.



Imagine you had arranged for your favourite aunt to come and visit you and suggested she gets off the train at a certain railway station where you would meet her.



If she called you to say she had made a mistake and missed the stop and had got off the train at the next station a kilometre further along the line, what would you do?

You could go to collect her from the station where she actually is, even if that was not the original plan.

Or, you could ignore the actual situation and instead stick to the plan, by going to meet her at the station where she was supposed to be.

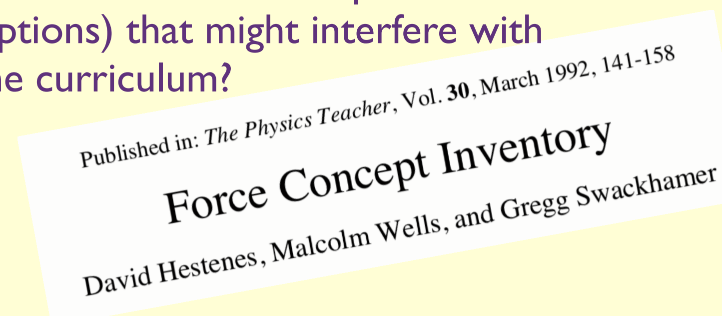
I wonder how many people listening today actually think it would be better to go the planned station to meet someone that you actually know is somewhere else? Perhaps no one. Yet, teachers are encouraged through the instruments of curriculum documents, schemes of work, and formal exams, to do this all the time.

Diagnostic assessment

Finding out what learners already know:

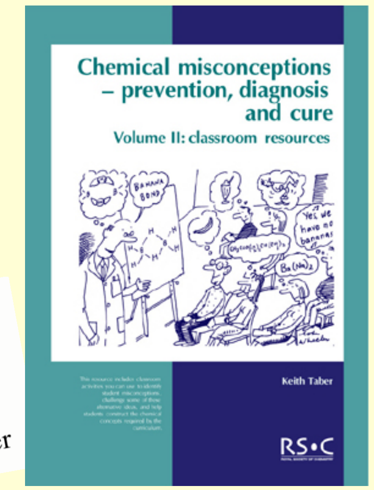
Have they covered the basics (- have they mastered the pre-requisite knowledge for further learning?)

Do they have alternative conceptions (misconceptions) that might interfere with learning the curriculum?


Published in: *The Physics Teacher*, Vol. **30**, March 1992, 141-158

Force Concept Inventory

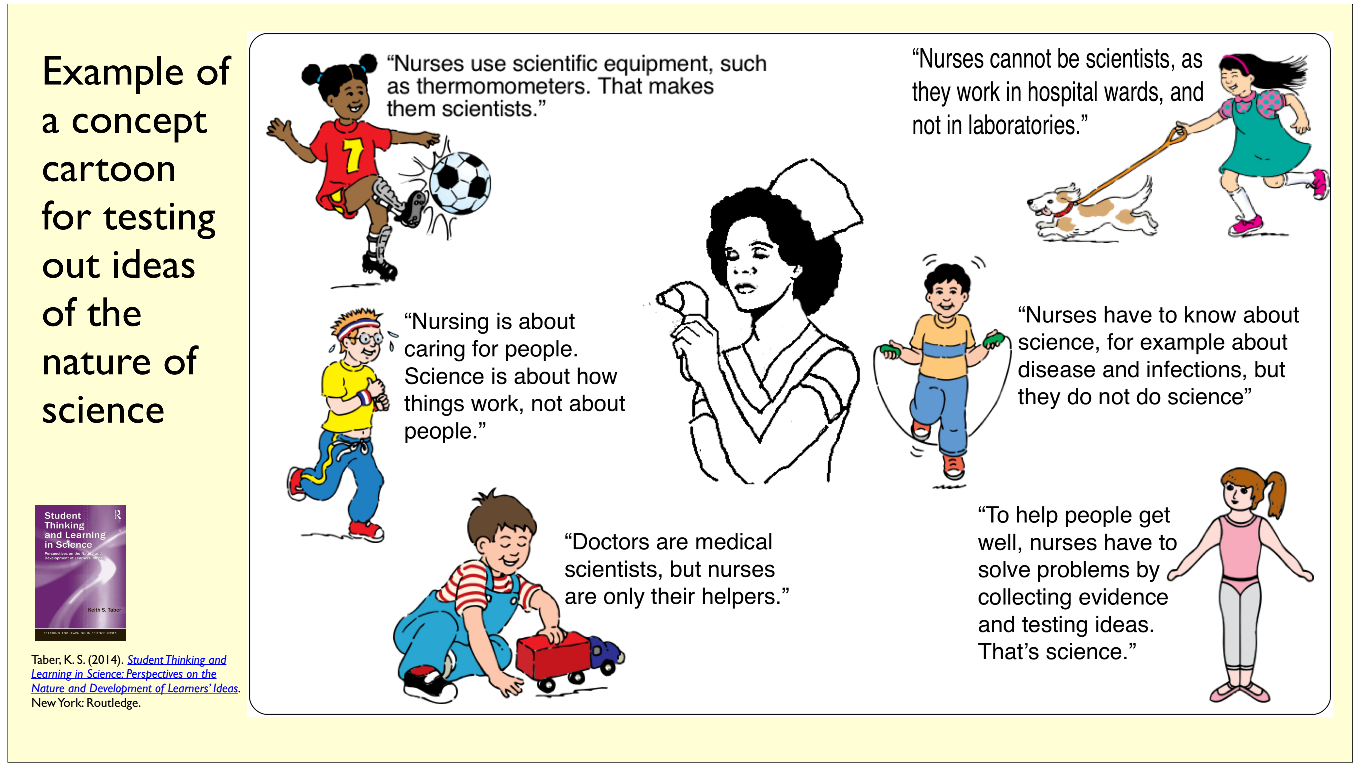
David Hestenes, Malcolm Wells, and Gregg Swackhamer



Taber, K. S. (2002). *Chemical Misconceptions – Prevention, Diagnosis and Cure: Classroom resources* (Vol. 2). London: Royal Society of Chemistry.

What this means is that teaching should always start with diagnostic assessment - finding out where learners currently are.

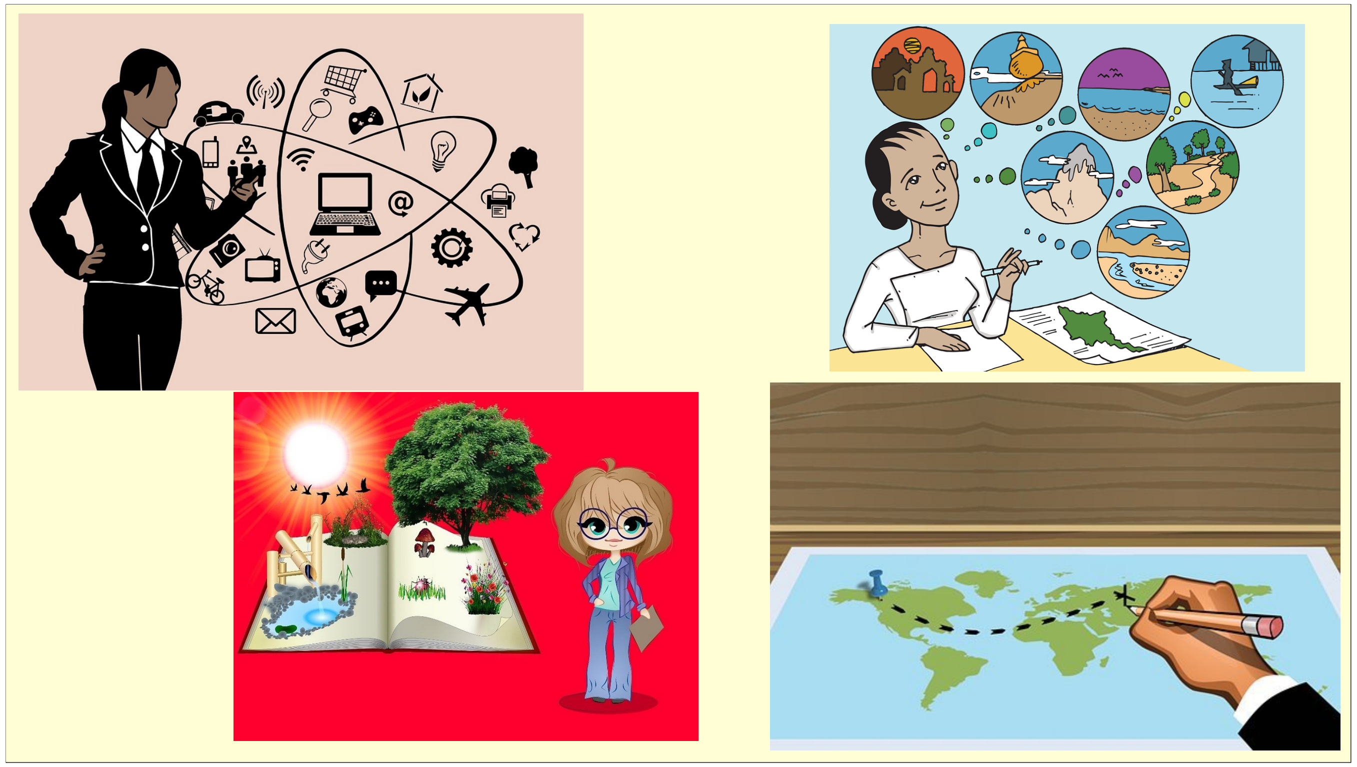
Have they covered expected prerequisite knowledge?
Do they have common alternative conceptions that will interfere with understanding the concepts to be taught?



Diagnostic assessment need not mean a formal exam. There are plenty of probes that can be used, such as concept cartoons, or tasks like concept mapping, and often these activities can be set up as paired or group work, to be followed by classroom discussion.

The aim is not to grade or score, but to learn about the students' current understanding and thinking. So it is not a problem if students work together. This is actually likely to be useful as the teacher can learn a good deal from listening to their conversations.

If it makes sense to you that you should share, rather than ignore, the learner's starting point, then I think my next slogan is likely to resonate as well.

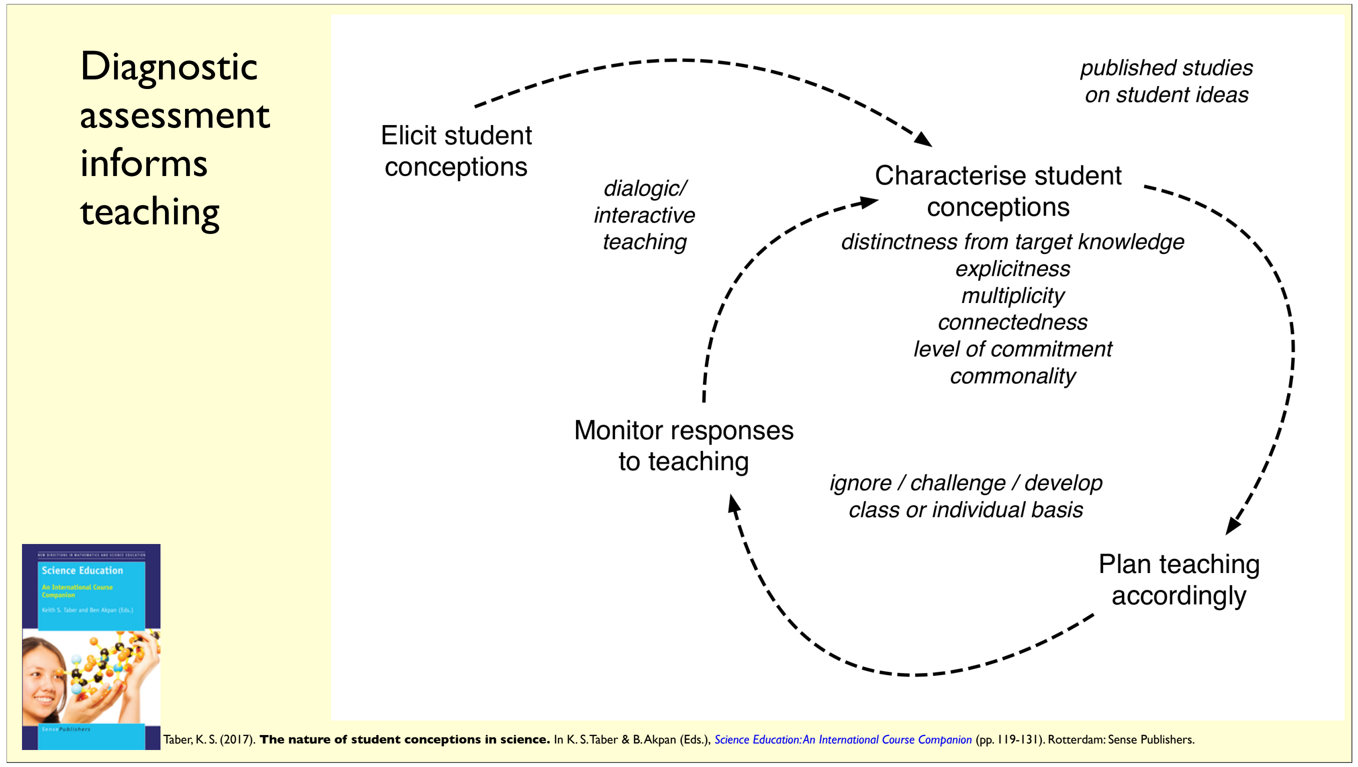


The teacher has expert knowledge of the topic to be taught and the subject that it is drawn from. The teacher can devise a logical route for the conceptual journey. The teacher can see which features of the scenery are important to notice, and what the significant stopping-off points should be. An effective teaching scheme has to reflect disciplinary structure and logic, and it has to emphasise the pedagogically most important matters.

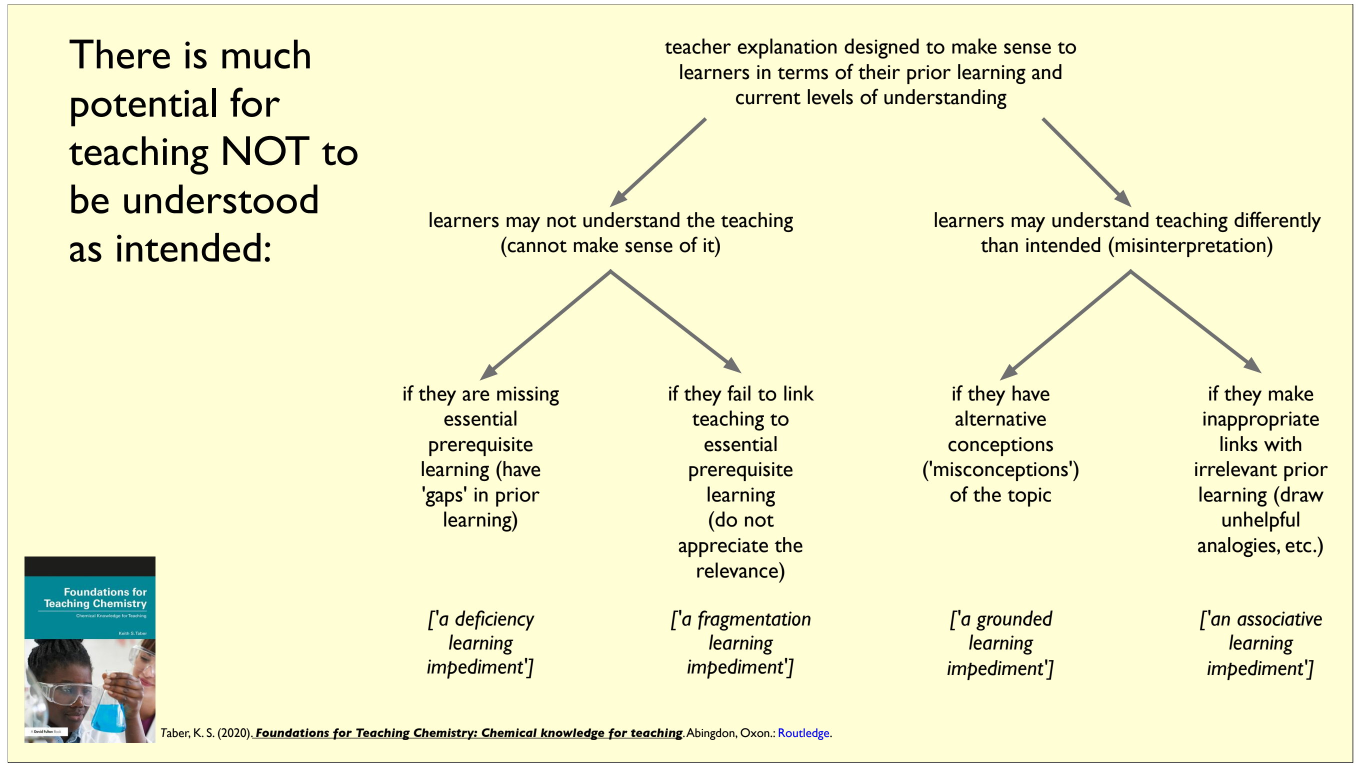
Of course, the learners do not yet have access to the disciplinary structure and logic, as that is exactly what they are meant to be learning.

So, from the learner's perspective the subject or topics may look very different. As they explore the scenery they may easily become fascinated by points which are not very important or relevant from the expert perspective, and they may be easily enticed down side streets or alleyways which can take them off course.

When on the logical journey of conceptual learning, a short detour could mean we never really catch up with the teacher.



The teacher needs to keep in mind that because of their expertise they have an overview of the territory and a familiarity with the destination not available to learners who are just having the experience of finding their way around a new location, and for whom the intended destination is not yet in sight.



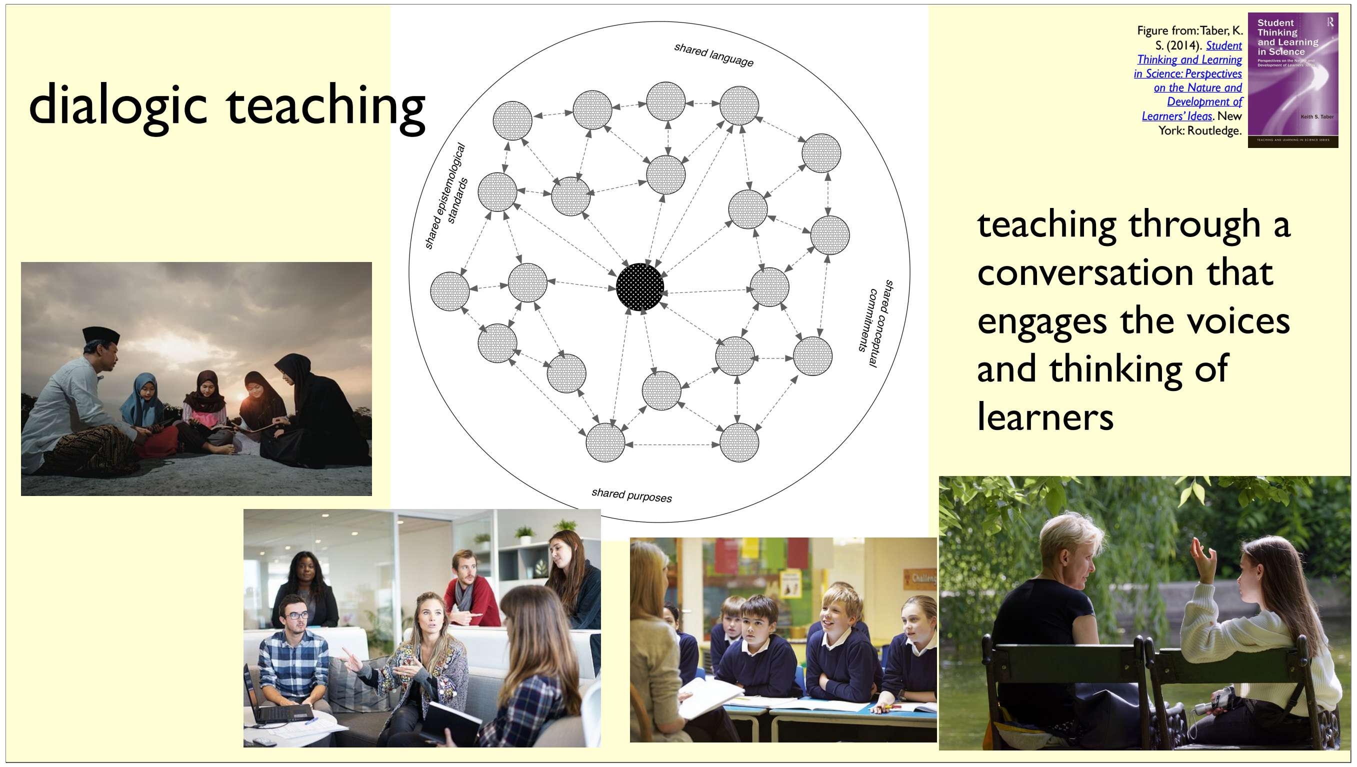
A teacher's presentation is designed to be understood by learners, and it is assumed they will have available the background knowledge, and will understand how and when to link new material with those foundations.

Yet they may be missing prior learning,
or may not make the expected links with previous lessons,
or they may interpret teaching in terms of non-canonical alternative conceptions,
or they may make creative but unhelpful links with unrelated background knowledge.

The teacher therefore does not just point the way, but needs to be there to cajole and encourage;

and to respond to what may be genuine, if not entirely pertinent, questions;

and to carefully take learners by the hand when they are in danger of inadvertently taking a wrong turn.

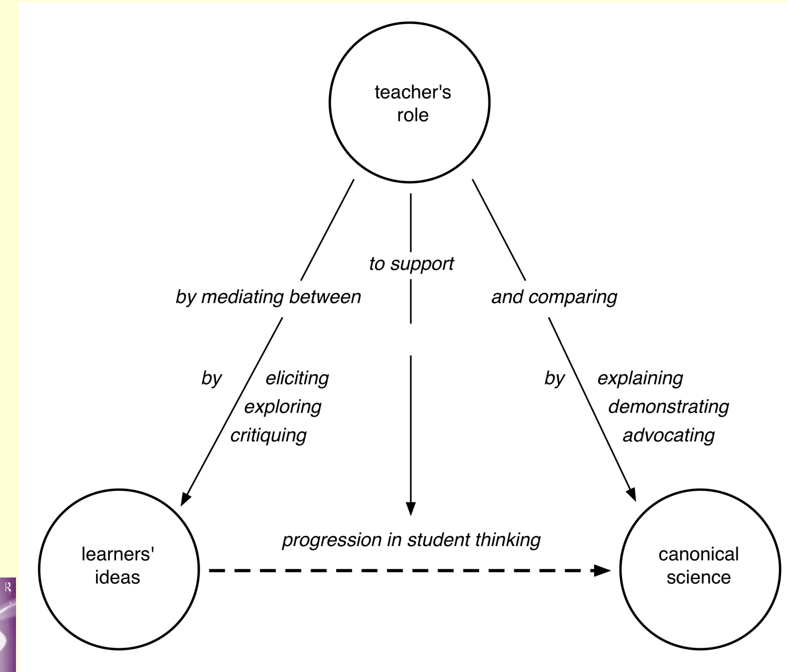


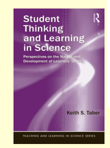
That is of course, all metaphor.

What this actually means is teaching in a conversational way. This does not mean being overly informal or focusing on social talk rather than the discipline itself. When the teacher talks and the students only listen, then the teacher may assume everything is understood as intended, but has no way to tell until the evidence of poor homework or disappointing test scores is available.

Teaching is not filling an inert vessel with information, but facilitating a learner who already has ideas, beliefs, viewpoints, … to question and develop their thinking

(persuading, not simply telling)





Taber, K. S. (2014). *Student Thinking and Learning in Science: Perspectives on the Nature and Development of Learners' Ideas*. New York: Routledge.

What is needed is ongoing dialogue, which offers formative assessment that helps the teacher to see *where the students actually are* - to see if they have wondered into the shopping centre when they were meant to be heading on to the museum. In this way, the teacher deals with misunderstandings and misinterpretations, or failures to make sense, at the time, rather than only discovering them later.

In school teaching this is likely to mean that most of class time is spent on activities where the learners work with ideas and the teacher can monitor what they are saying, doing, and writing.

In lecture courses it is possible to interject various short activities into lectures such as quick multiple choice questions, or asking students to work in pairs or small groups on some question or discussion point. Active learning means active minds, and even mature students who can concentrate on listening to an engaging teacher for modest period benefit from short breaks to process what they have heard.

My next point is closely related to the last one, in that it concerns the planning of the conceptual journey that the teacher is hoping to take the learners on.

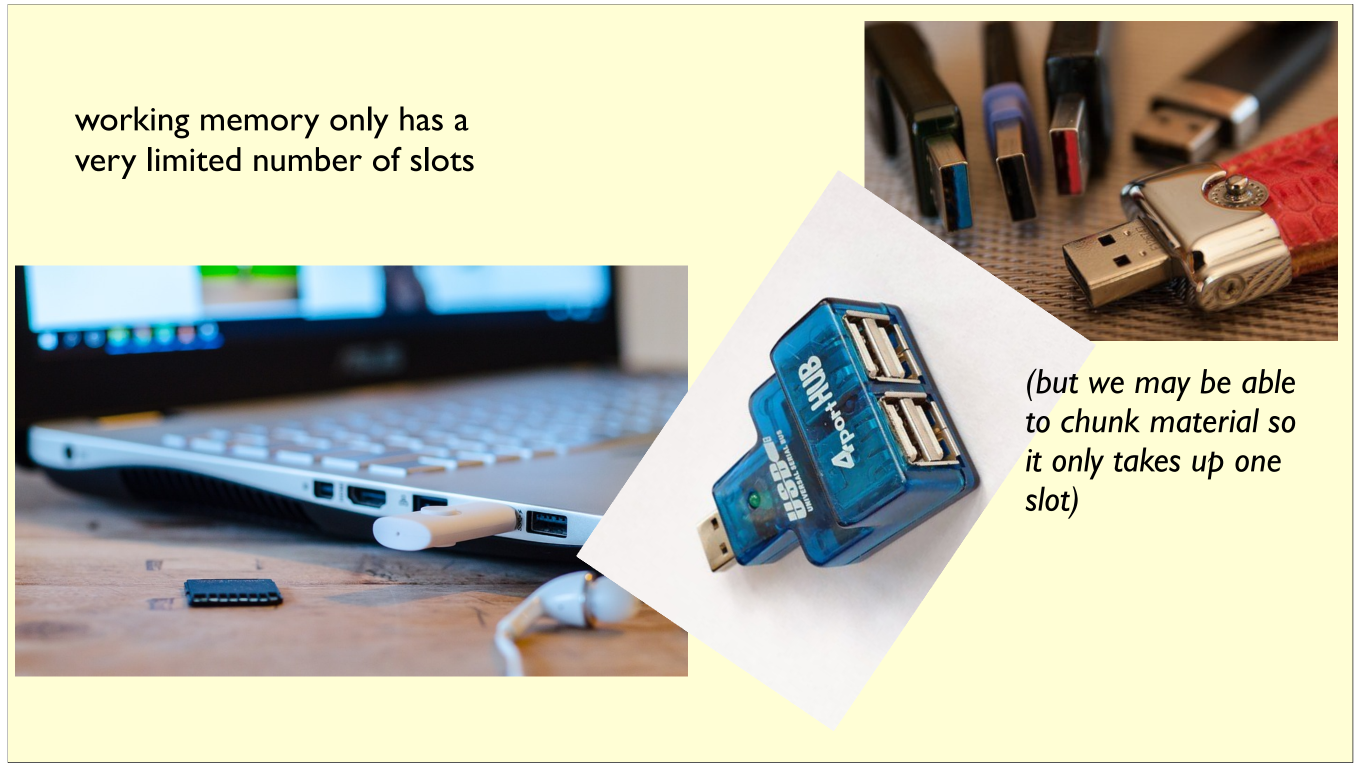
One of the key features of human learning is the limited capacity of working memory which is central to all the deliberate thinking we do.

https://science-education-research.com/learners-concepts-and-thinking/memory/working-memory/

Working memory is where we plan, and where we do the conscious part of problem solving, and where we test whether we understand things, and where we make those connections between what we are being told now and what we already know and understand.

Even though our brains are at any time dealing with a wide range of complex information, in working memory we focus on only a tiny fraction of this at any moment.

The term working 'memory' is unfortunate as information is only held there very transiently unless we actively rehearse it, and a better term might be the executive processor!



This executive processor may crudely be considered to have a very limited number of slots for information. Probably we have about 5-6 slots available at most to do any of the deliberate mentipulation necessary to study, or to address problems, or analyse a situation.

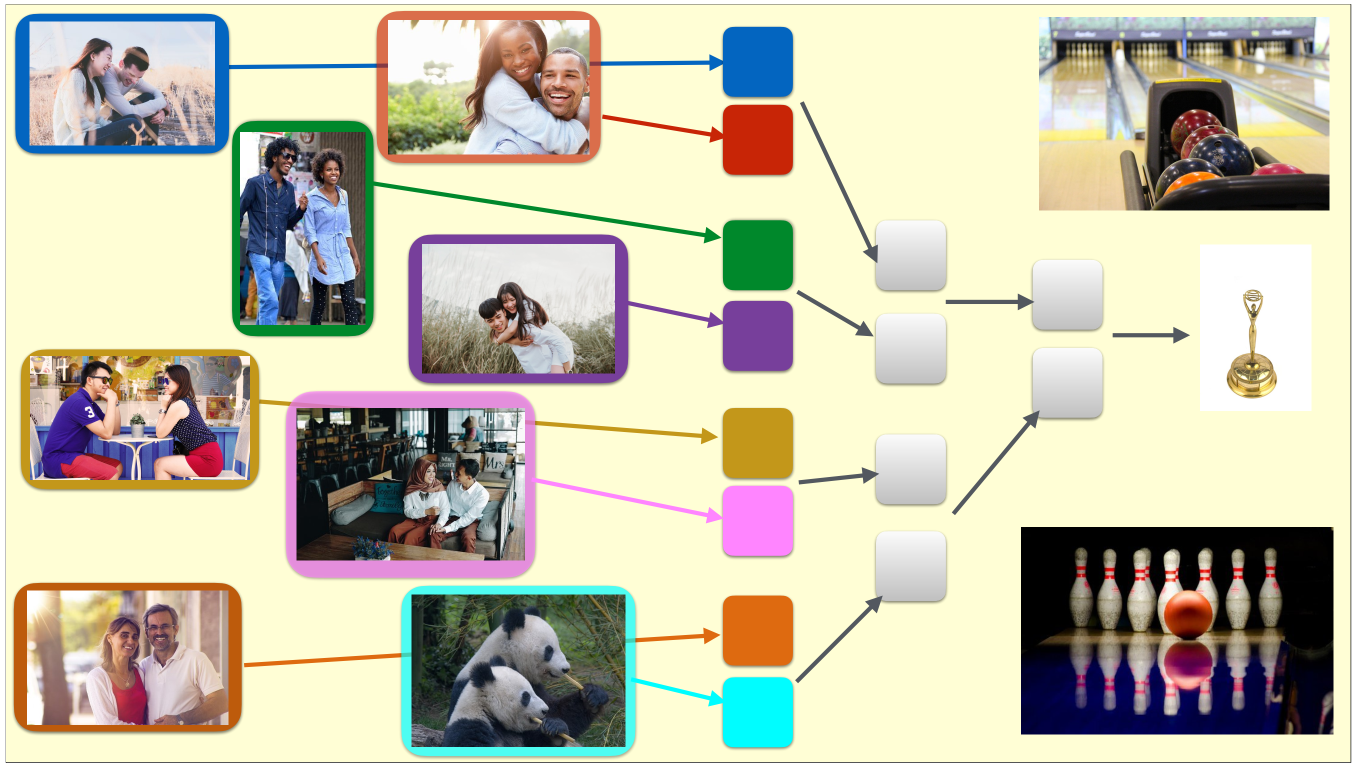
Once we reached adulthood, the number of working memory slots is then fixed for the rest of our lives. But we can use those slots more effectively due to a process called chunking. Chunking is where we learn to appreciate complexes as coherent wholes.

Someone who had never seen a bicycle in their life might on first coming across one not recognise a single machine, but perceive the wheels and handlebars and chain and brake pads and pedals and frame and as discrete objects. We have learned to see the bike as a single unit.

Imagine you got to know Farah when she came to work in the faculty.

You also met Ashraf when he joined your badminton club.

When Farah invited you to her birthday party she introduced you to her husband, Ashraf. Whilst you still recognise Farah and Ashraf as unique individuals, you also now know Farah and Ashraf as a couple - so you are also able to think of them as one entity.



If you were arranging a couples ten-pin bowling competition you will think of inviting Farah and Ashraf to collectively take up one slot.

The important point here is that you have not lost knowledge of Farah or Ashraf as discrete people, but are able to both see them as a couple, and also to analyse that entity down to its component partners. This is a simple example, but the principle is broad.

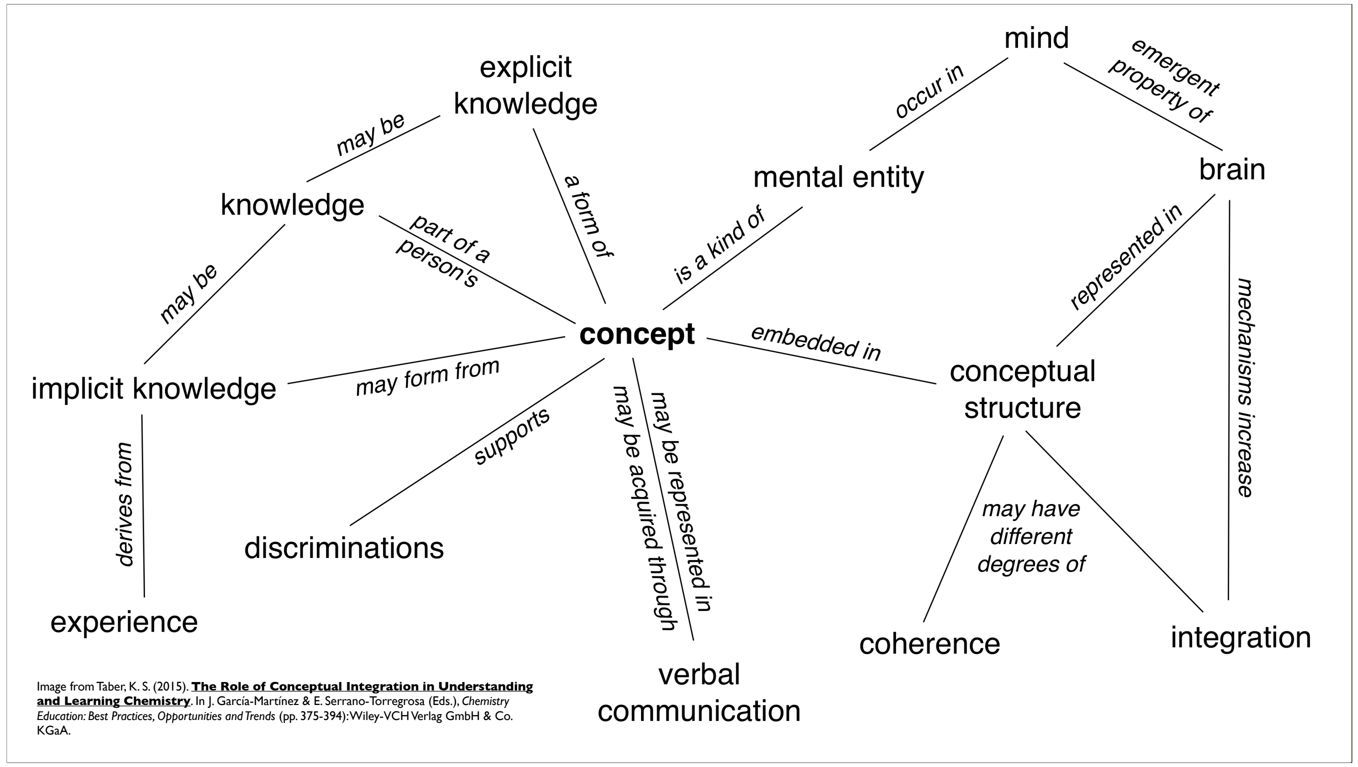
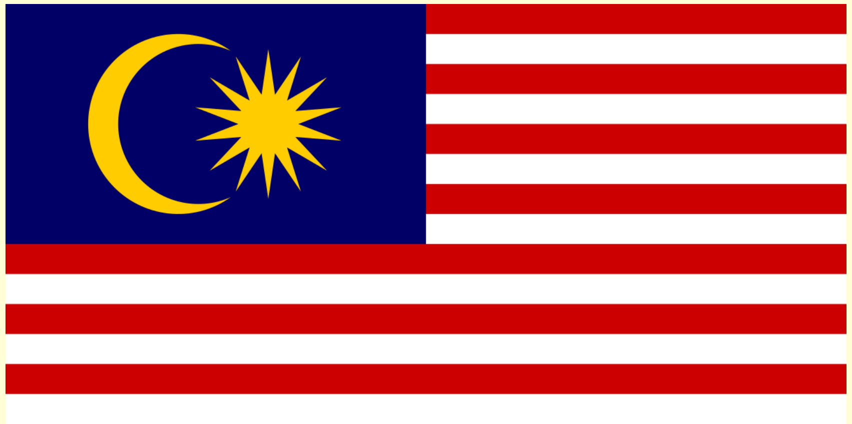


Image from Taber, K. S. (2015). **The Role of Conceptual Integration in Understanding and Learning Chemistry**. In J. García-Martínez & E. Serrano-Torregrosa (Eds.), *Chemistry Education: Best Practices, Opportunities and Trends* (pp. 375-394): Wiley-VCH Verlag GmbH & Co. KGaA.

We learn to built up complexes that we can treat as one item, but which we can still decompose to their constituent parts as well. This means that the complexity of some object or conceptual framework in relation to how it can be mentipulated is subjective depending on the familiarity of the material to different individuals.

Describe this image:

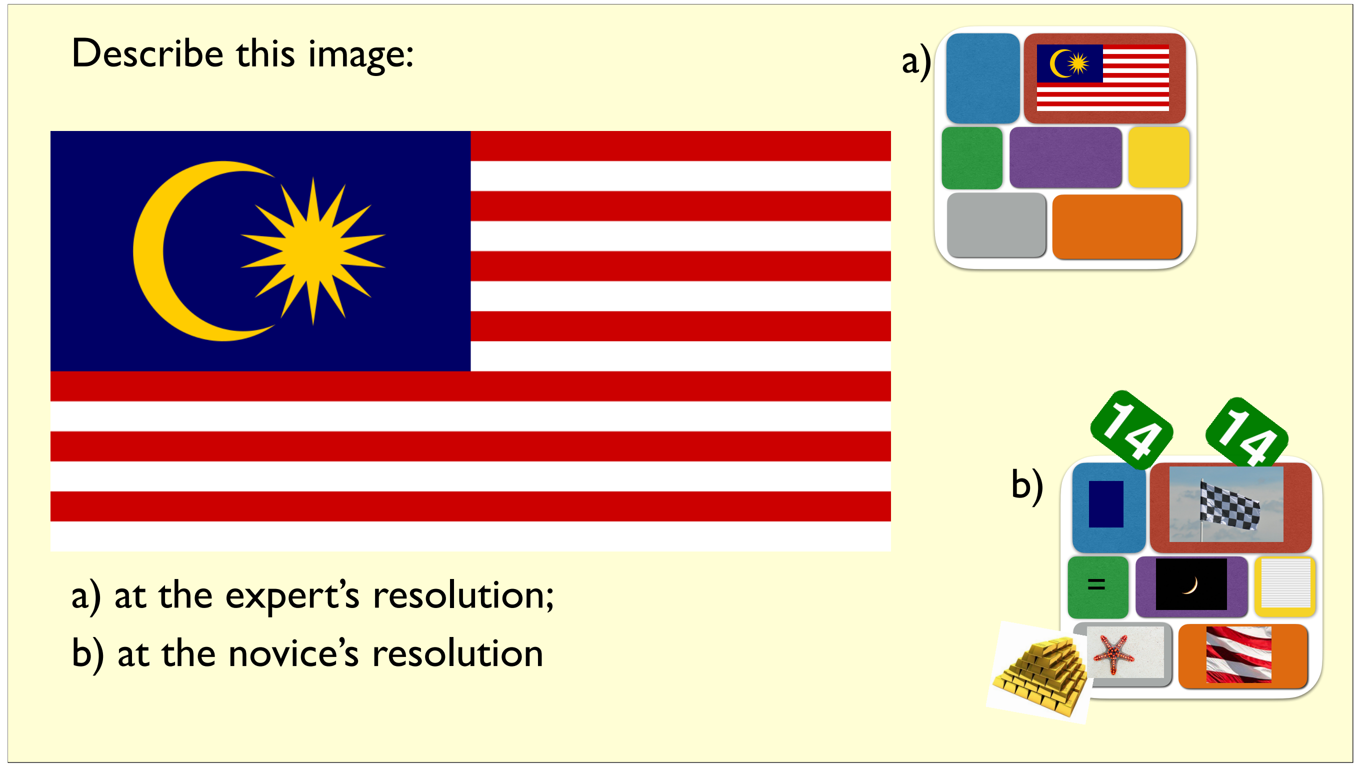


a) at the expert's (someone very familiar with the material) resolution;

b) at the novice's (someone completely new to this image) resolution

Here is an image. Most of you will recognise this immediately. If you wanted to tell someone later what you saw you would tell them it was the Malay flag, and they would immediately know what you had seen. It occupies one slot in the memory!

[This activity was included in the pre-lecture at https://science-education-research.com/about-keith/universiti-teknologi-malaysia/constructivist-teaching-lecture-preview/]



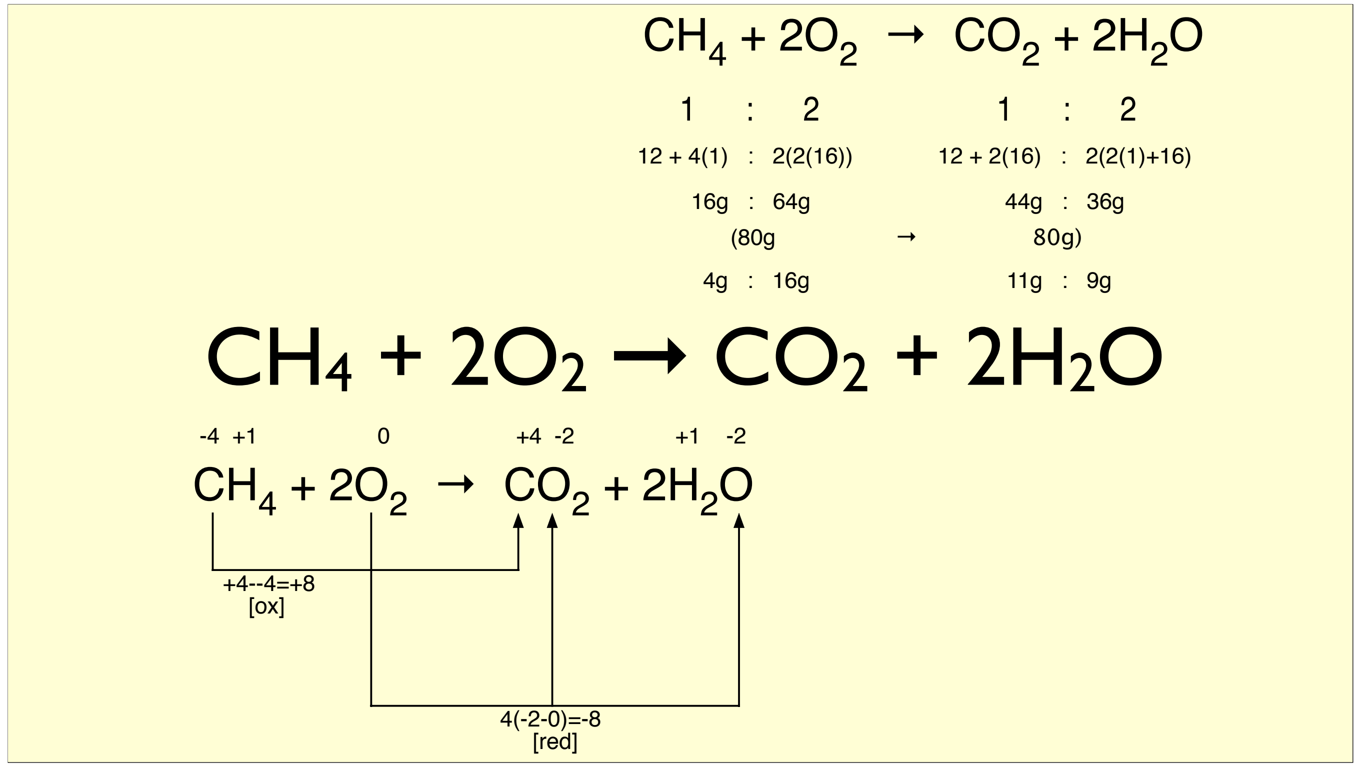
However, if I was telling someone in my family, who is not familiar with Malaysia, about the image, I would have to explain that it was a flag, - then describe how it was divided into two regions, - the top left quarter having a royal blue background - and gold symbols - of a crescent - and a 14-point star, - and the rest being 14 alternating - red and - white stripes - of equal width - with the top stripe being red.

That might be enough to exceed memory capacity. The 'same' information can be treated as one unit when it is chunked, but it is only chunked when someone has previously spent time and effort familiarising themselves with it. That is, if I asked you to think about or remember this image, you already know it and can visualise it as an organised whole.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Here is another example.

For a chemistry teacher, an expert, this is understood as a single coherent chunk of information that fits within one slot of working memory. It also immediately suggests a wide range of other associations such as types of substances, and reactions. It embodies ideas about conservation of mass. It links a description of how substances behave to a model in terms of molecules and chemical bonds. Yet all of that is learned, and to a novice this is a complex string of symbols that does not yet have any unitary coherent identity.



These two additional schemes link to ideas about conservation of mass, and conservation of charge, and must look to a novice to add a whole complex mess of additional detail, but to an expert all of this material is familiar and fits into a coherent scheme. Indeed, to the expert, all this additional material is already inherently implied by, and implicit in, the original equation!

Can you think of examples from your discipline / curriculum area of concepts and representations

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

that seem very complex when first met but which become understood as single coherent ideas/ images with developing expertise?

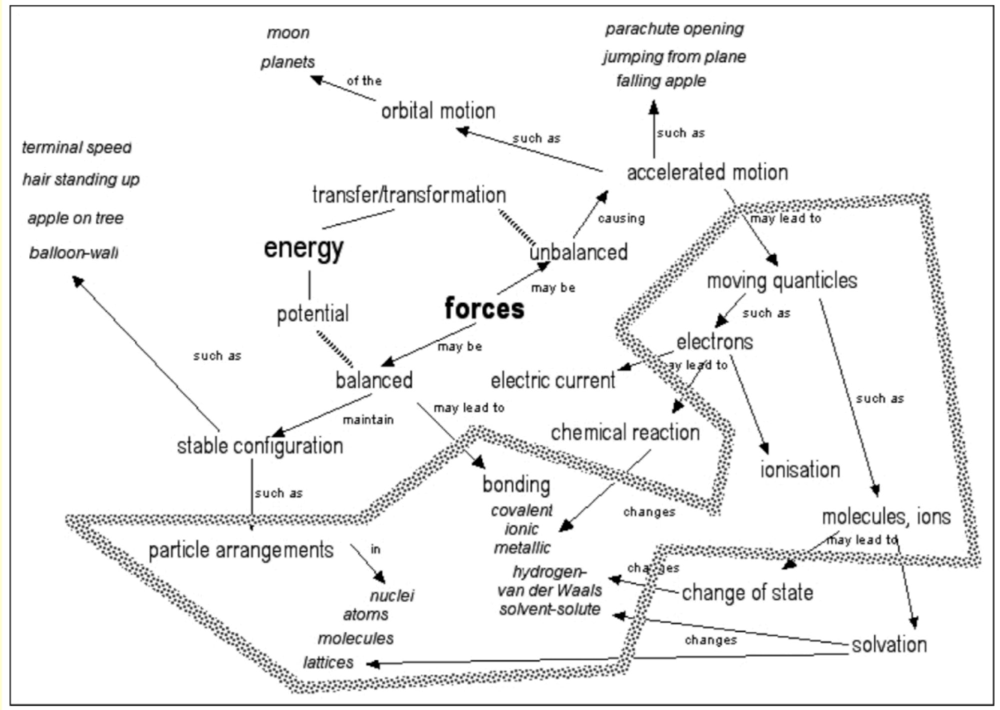
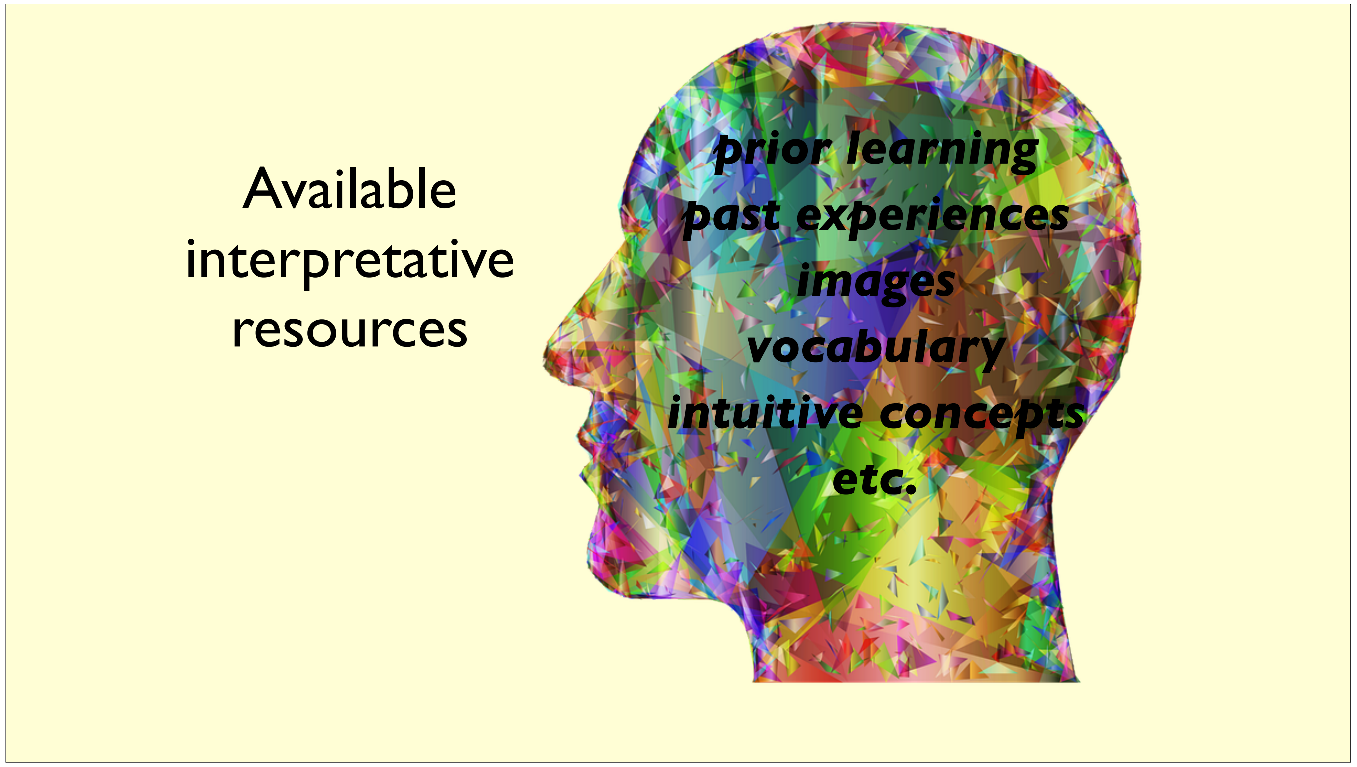


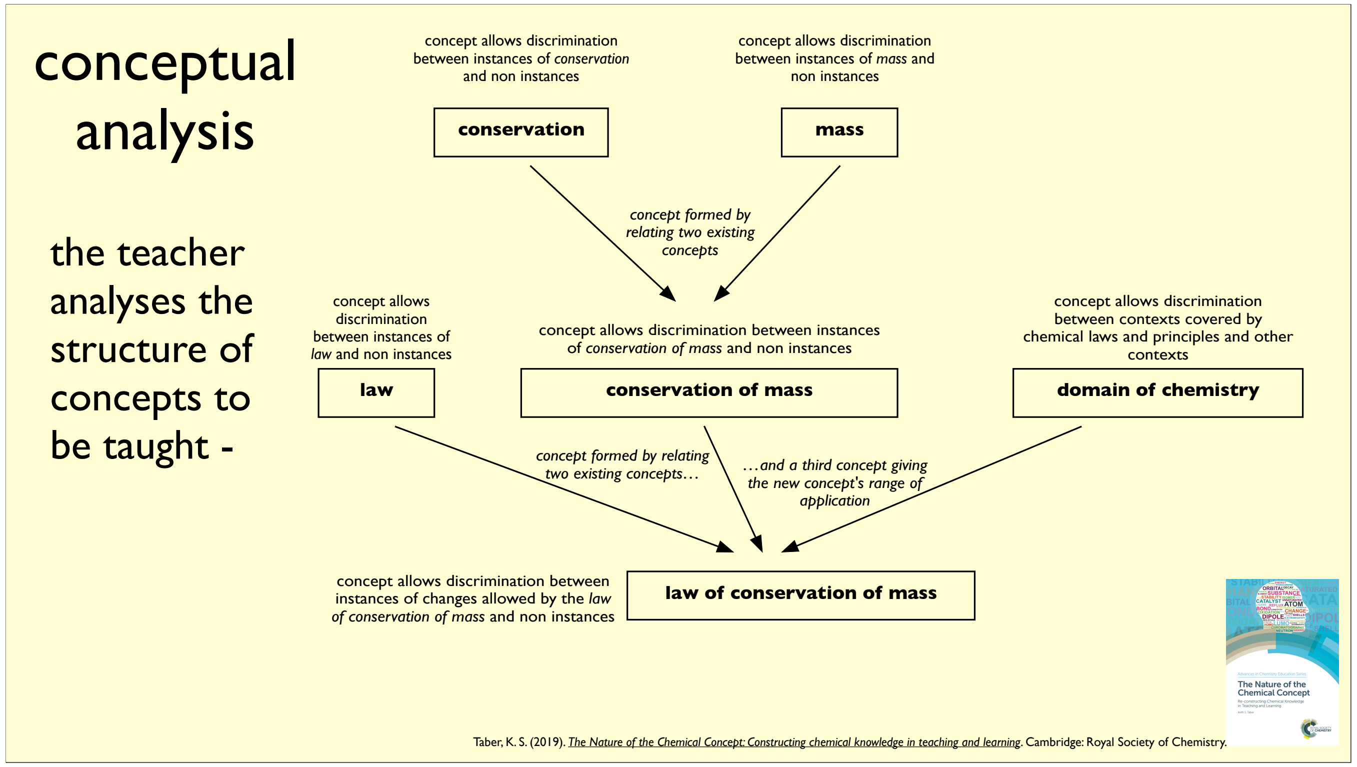
Figure from: Taber, K. S. (2008). Exploring conceptual integration in student thinking: evidence from a case study. *International Journal of Science Education, 30*(14), 1915-1943. doi:10.1080/09500690701589404

It is the linking and association of related ideas that enables the expert to both chunk complex material and to move about the conceptual web of their discipline with relative ease. None of this is available to a novice.



A teacher planning a lesson has to think how complex a concept or topic might appear to a learner, and what interpretative resources they have to understand it.

It is not how this conceptual journey appears to the expert that matters, but how it will be seen from the perspective of the novice with limited background knowledge, fragile prior learning, and limited integration of material into conceptual networks.

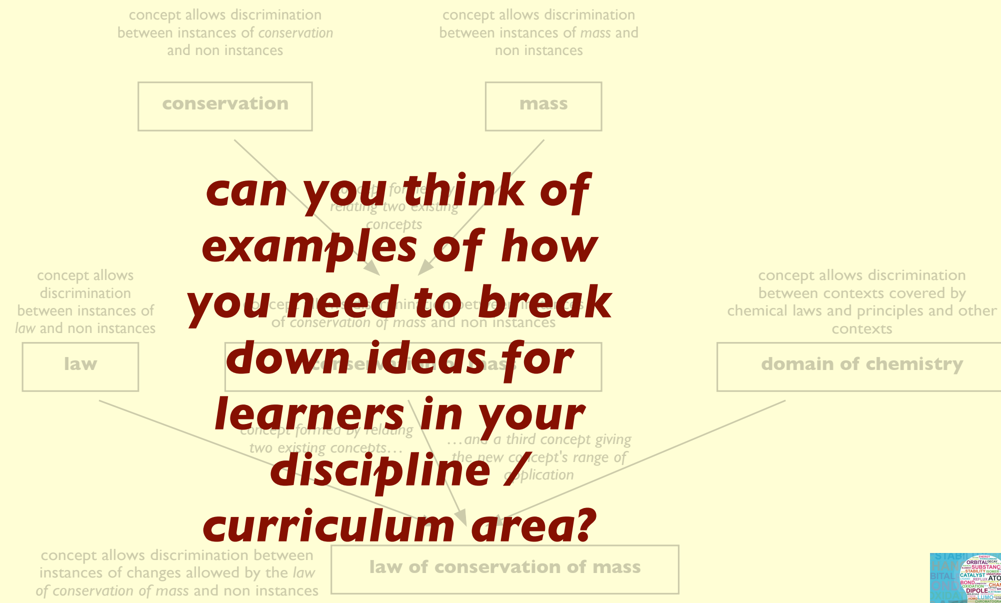


Our teaching will be seen at the learner's resolution, not the teacher's, so it needs to make sense at the learner's resolution. So when breaking down a topic into learning quanta, these must be manageable and digestible quanta of learning from the learner's own perspective.

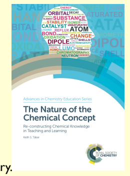
It is no good giving a new born baby a Greek salad for dinner, on the basis that it works as a meal for the parent.

conceptual analysis

the teacher analyses the structure of concepts to be taught -

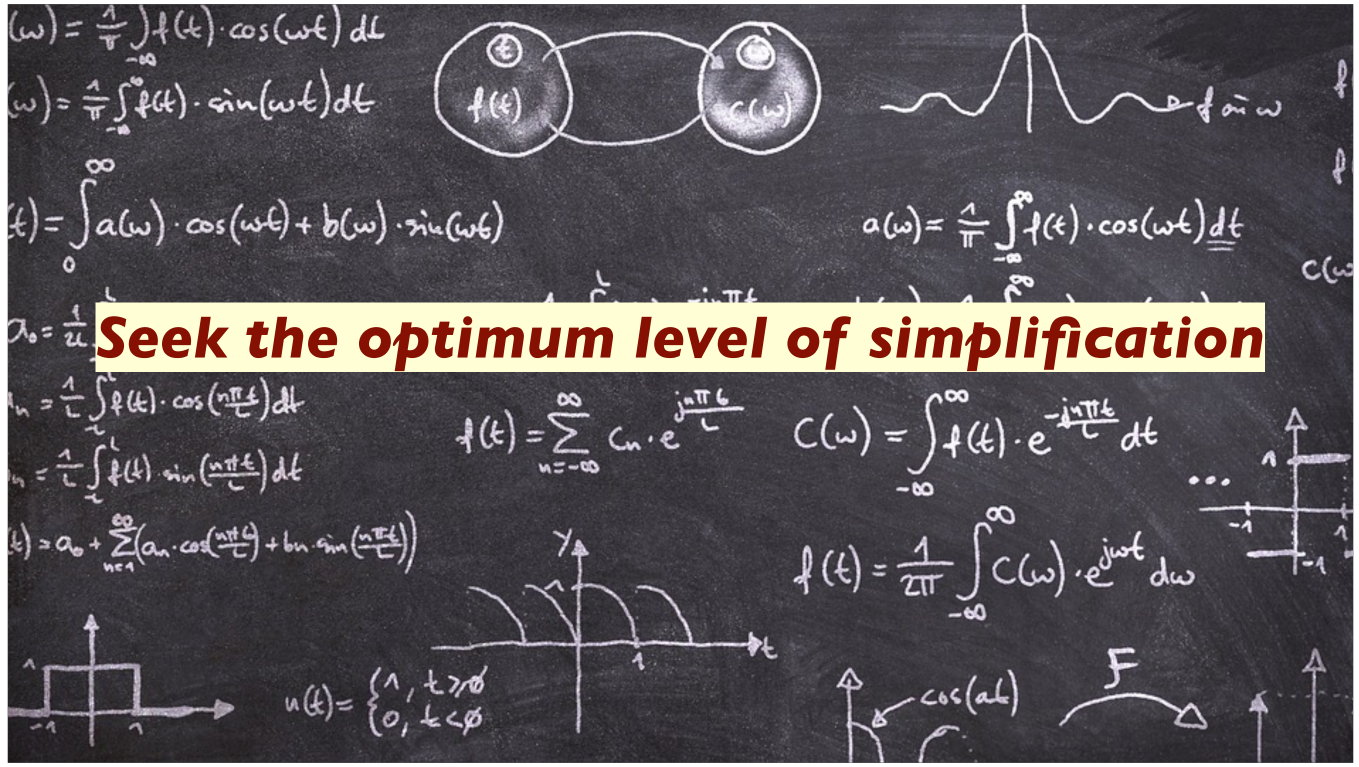


can you think of examples of how you need to break down ideas for learners in your discipline / curriculum area?

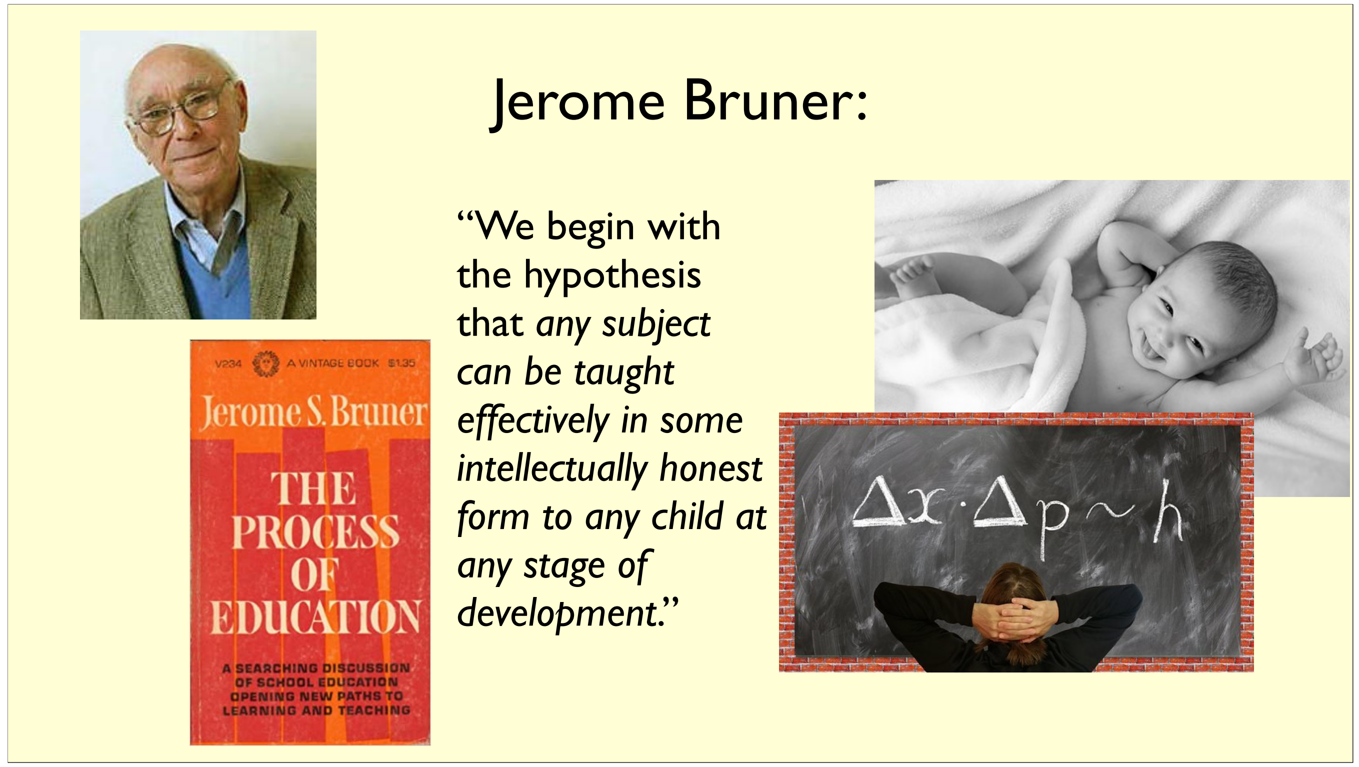


Taber, K. S. (2019). *The Nature of the Chemical Concept: Constructing chemical knowledge in teaching and learning*. Cambridge: Royal Society of Chemistry.

Seek the optimum level of simplification



The educational thinker Jerome Bruner famously claimed that we could teach a learner of any age any subject in an intellectually honest way.



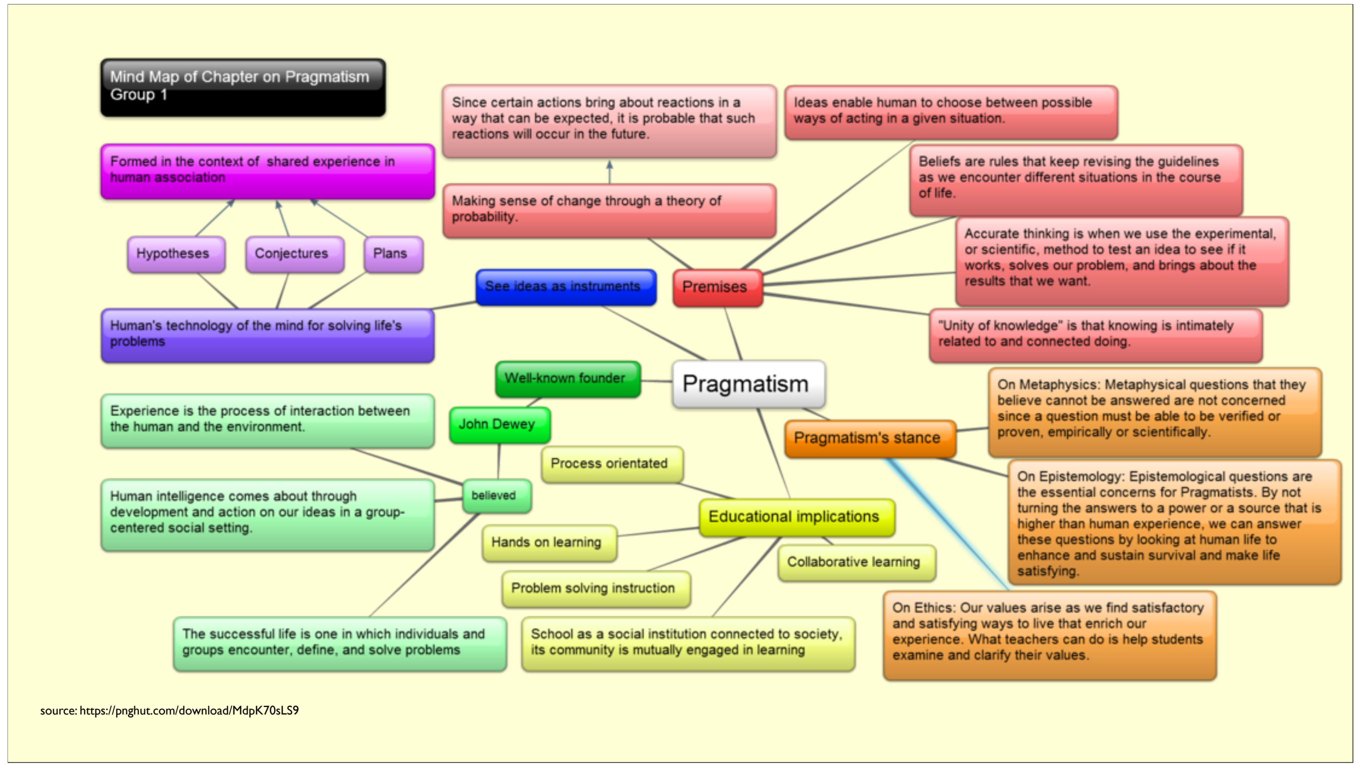
What he meant by intellectually honest was that although we may teach a simplified version, not the 'whole truth', it would still be an authentic account - it would still be true, if not comprehensive.

I suspect Bruner was being a little provocative but his claim is certainly one teachers can find aspirational.

‘the’ concept of ‘oxidation’

addition of oxygen	*inferred from observations*
addition of oxygen or removal of hydrogen	*assumes a formal equivalence based on an abstract scheme*
loss of electrons from molecule/atom/ion	*inferred changes in hypothetical entities at non-observable scale*
reduction in formal oxidation state	*relies on ‘oxidation numbers’ assigned in terms of a purely formal (non-feasible) scheme for how molecules would be fully divided into atomic ions*

Many of the abstract ideas we teach in education are very complex. Models and concepts that were originally simple may have over time acquired increasing levels of sophistication in order to be useful in thinking about a wider range of phenomena, or in order to predict more precise outcomes.



source: https://pnghut.com/download/MdpK70sLS9

Many ideas have been discussed by various thinkers adopting different perspectives and commitments so that it is probably impossible to offer a simple account of, say, romanticism, or positivism, or pragmatism, or the baroque, which encompasses the breadth of scholarly thinking.

We cannot start teaching with the most advanced current canonical accounts of disciplinary knowledge, but need to simplify.

Every time we simplify something sophisticated by stripping away some of its complexity and subtlety we do two things. We both make it more accessible for a novice, and make it a less authentic version of the original.

‘the’ concept of ‘oxidation’

addition of oxygen	*inferred from observations*
addition of oxygen or removal of hydrogen	*assumes a formal equivalence based on an abstract scheme*
loss of electrons from molecule/atom/ion	*inferred changes in hypothetical entities at non-observable scale*
reduction in formal oxidation state	*relies on ‘oxidation numbers’ assigned in terms of a purely formal (non-feasible) scheme for how molecules would be fully divided into atomic ions*

can you think of examples from your discipline / curriculum area of concepts or models or theories that have become more complex, nuanced and subtle as developed over time by different scholars/intellectuals?

As an analogy think again about a bicycle. We all come to recognise the particular configuration of many parts that is a bicycle as a single object. We are able to immediately recognise a wide range of quite different bikes as being instances of the bicycle.

We could remove mudguards, the pump, the water bottle, the bell, the panniers, the lights, and the reflectors and we would have lost some utility that can sometimes be really valuable. But we would still have a basic bicycle.

But if we remove the chain, or the brakes, we have lost some of the core functionality that allows us to use a bicycle properly.

a bicycle?

If we remove one of the wheels, we do not even have a bicycle anymore, as it is part of the very essence of a bicycle that it has two wheels.

Some simplifications lose what is essential in an idea, such that the simplification may not be a good basis for later progression to more complex accounts, and such simplifications may even act as learning impediments that mislead students.

the optimum level of simplification

1) we simplify enough for ideas to be accessible to the learners based on the interpretive resources they have available

2) we do not simplify more than we need to to make the ideas accessible for those students

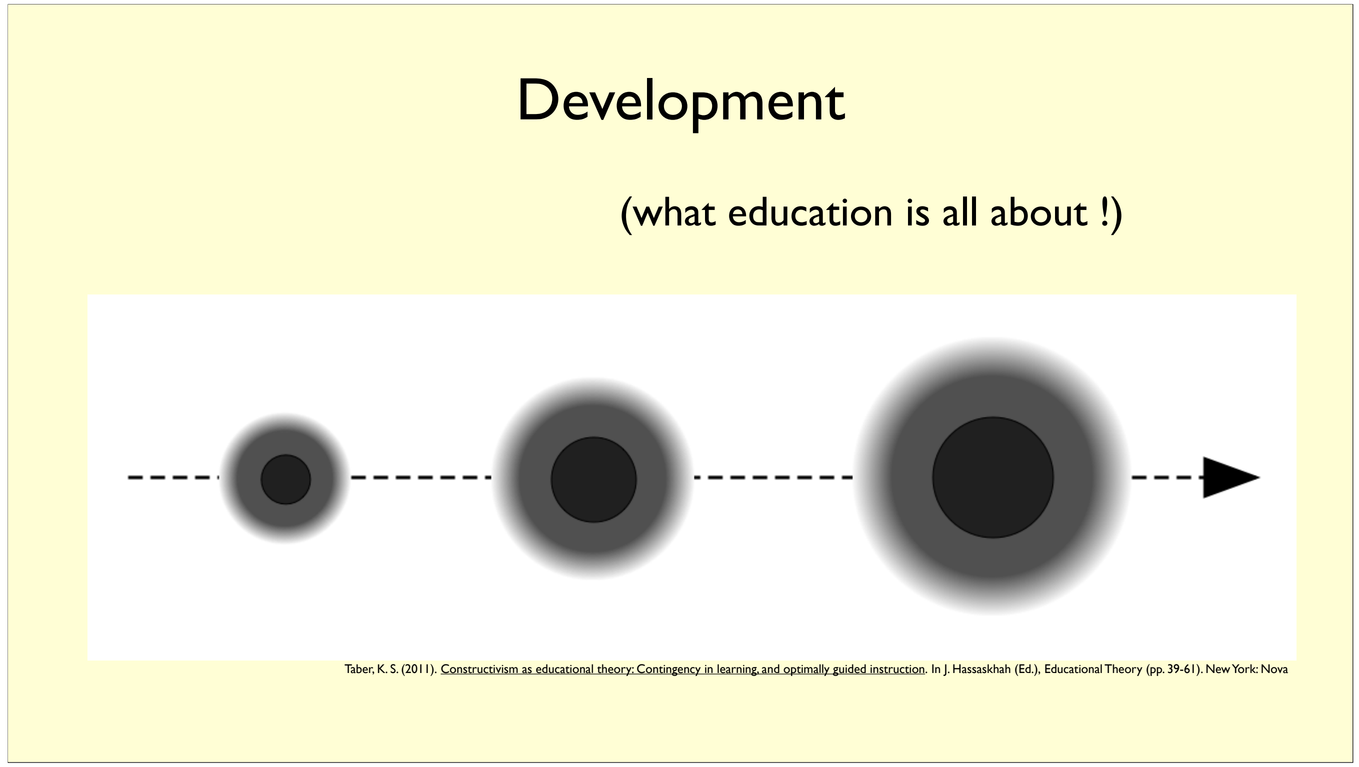
3) we do not simplify in ways that impede progression to more advance models/accounts that a student might meet later

There is then a tension - the more we simplify, the more accessible something becomes to a novice learner. However, the more we simplify, the less we are teaching an authentic version of the target concept or theory.

We need to find optimal levels of simplification. That is:
1) we simplify enough for ideas to be accessible to the learners based on the interpretive resources they have available
2) we do not simplify more than we need to in order to make the ideas accessible for those students
3) we do not simplify in ways that impede progression to more advanced models or accounts that a student might meet later

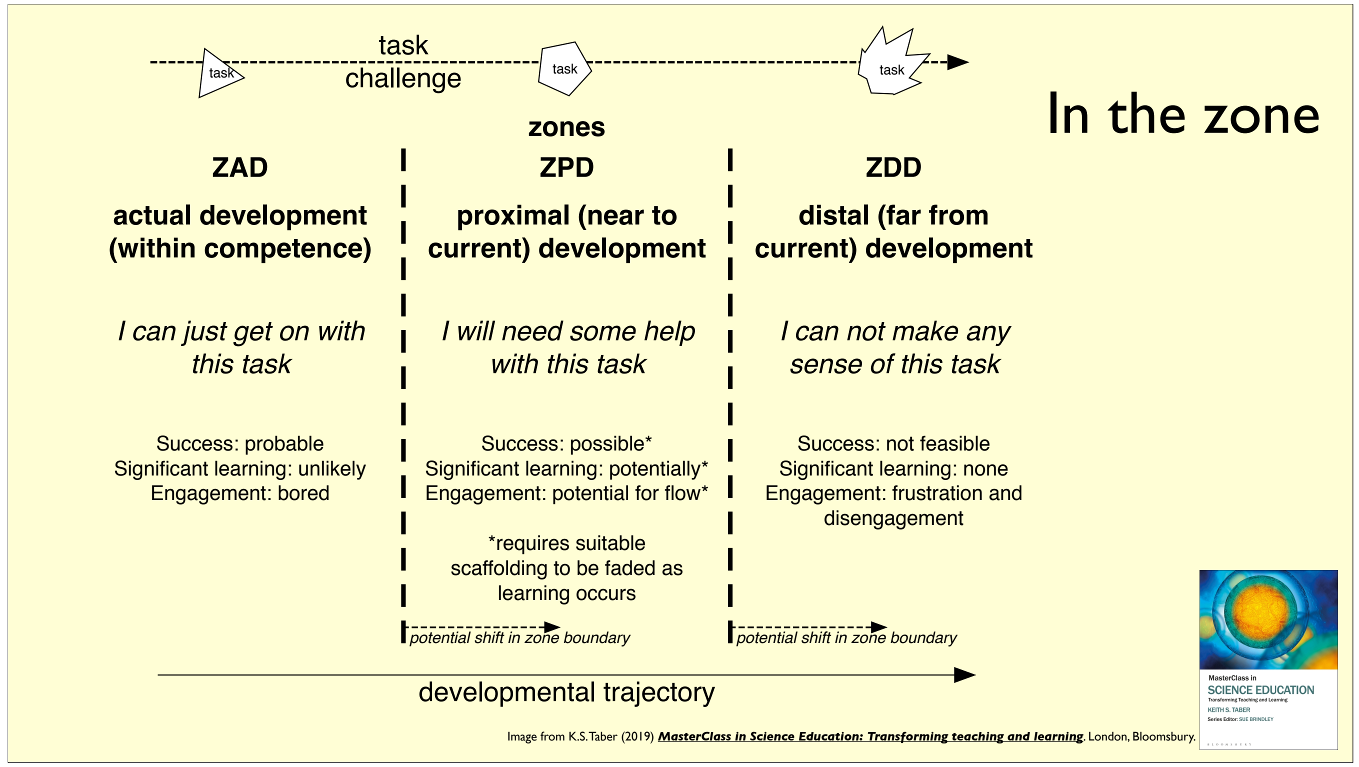
In my own area of teaching I have often seen simplifications presented in teaching getting in the way of learners making progress. This is one area where educational research can help teachers to know which simplifications are most optimal.

My next slogan also refers to finding a balance between opposing considerations.



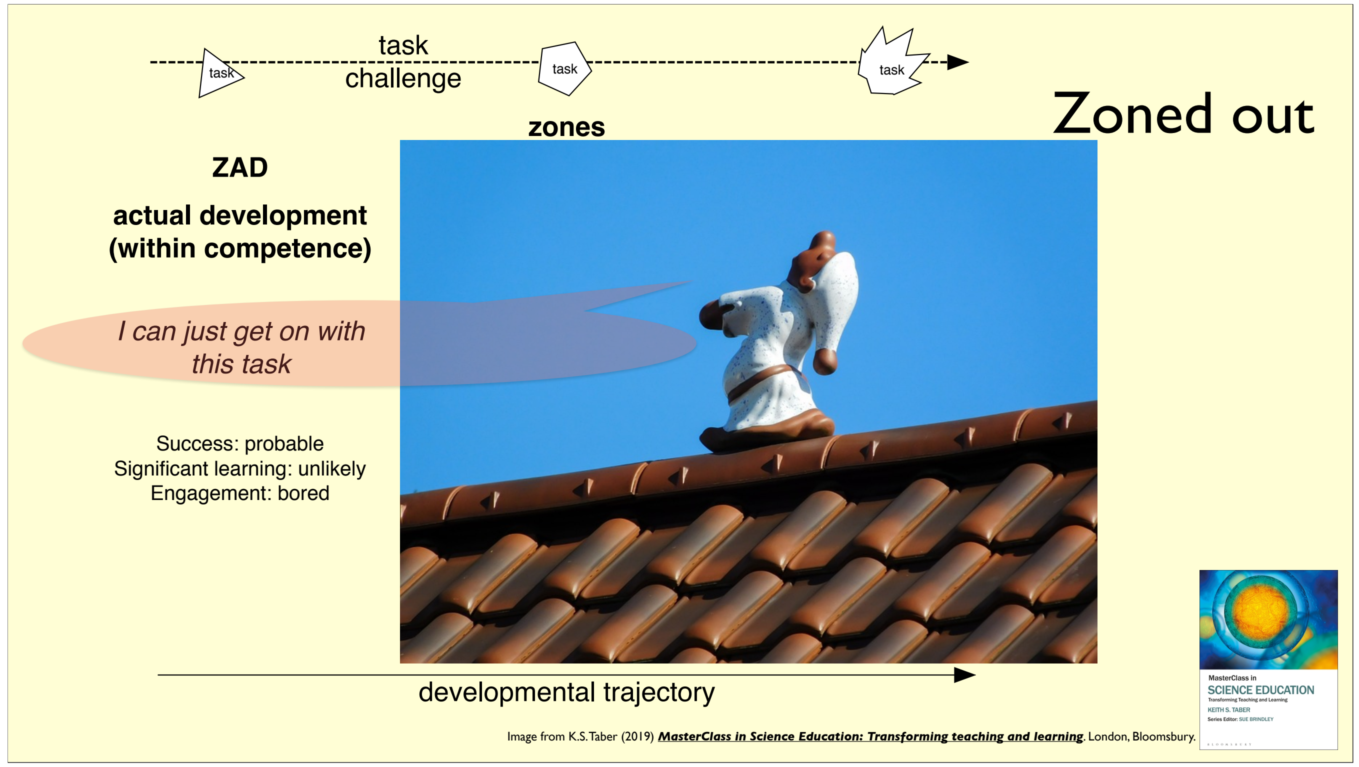
I want to make a rough distinction between learning activities which support development and those that do not. By ‘development’, I mean acquiring new skills, new concepts, new associations, new perspectives. This is surely what education is about.

Yet a lot of classroom activity involves students exercising the skills, knowledge and understanding they have already acquired, rather than moving forward. Now, I am not suggesting that exercising is not important, but I question if we always get the balance right.

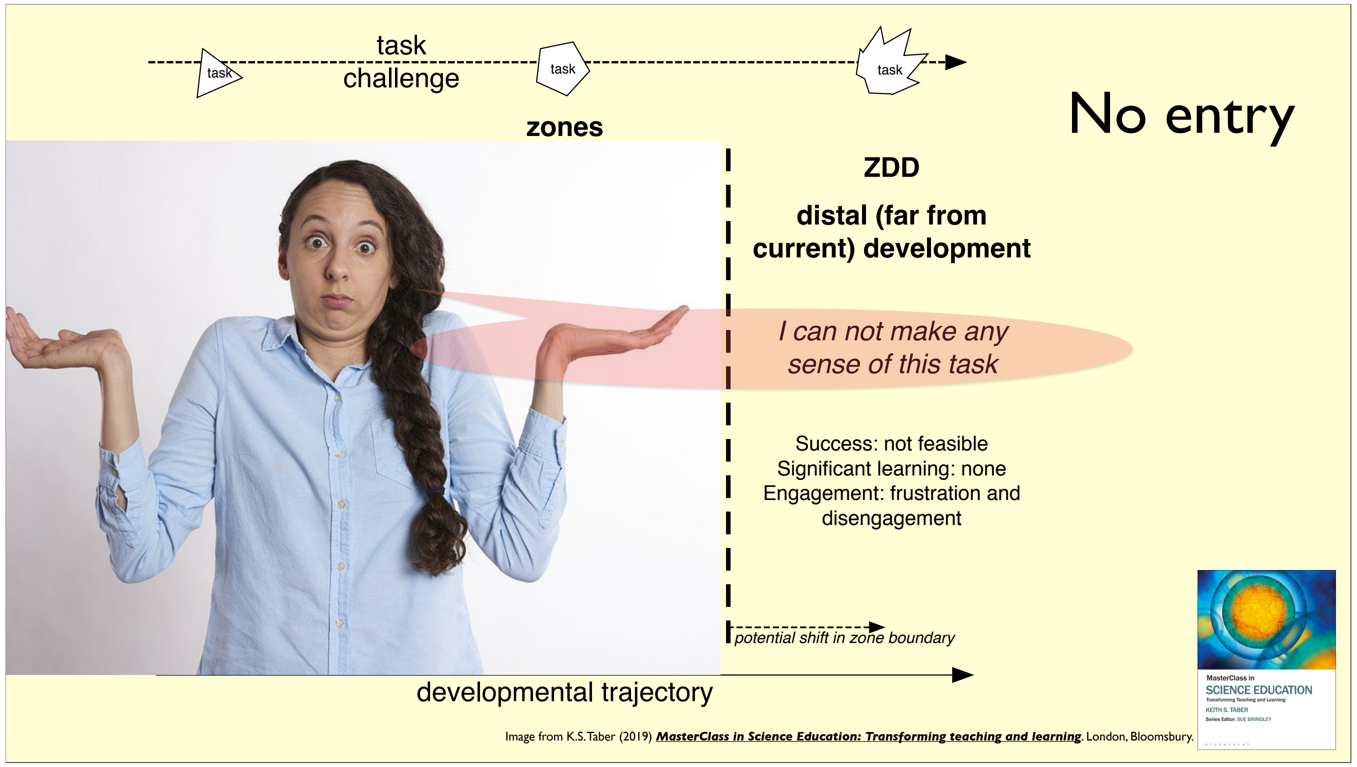


The polymath and educational thinker Lev Vygostky introduced the idea of a kind of imaginary multidimensional space which represents the individual's' various competences.

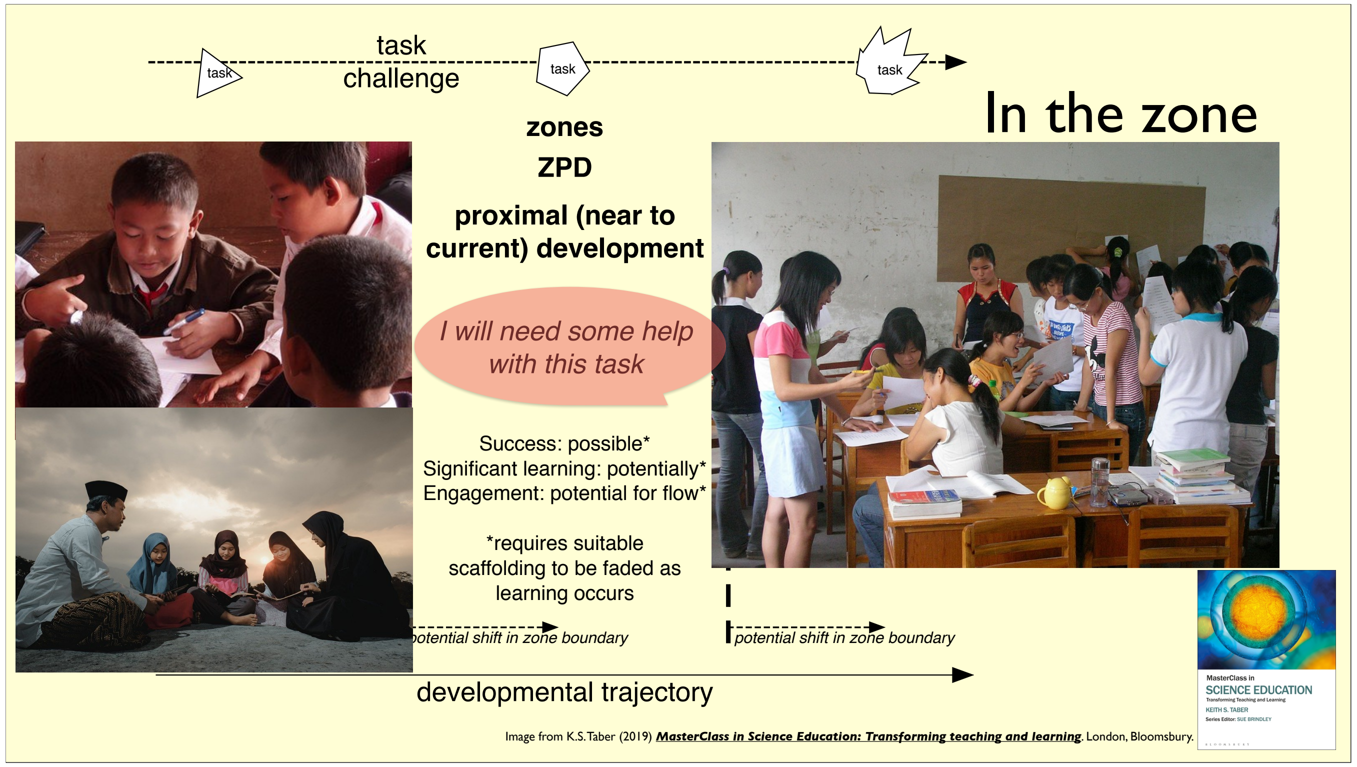
In relation to any particular area of learning this space is divided into three zones.



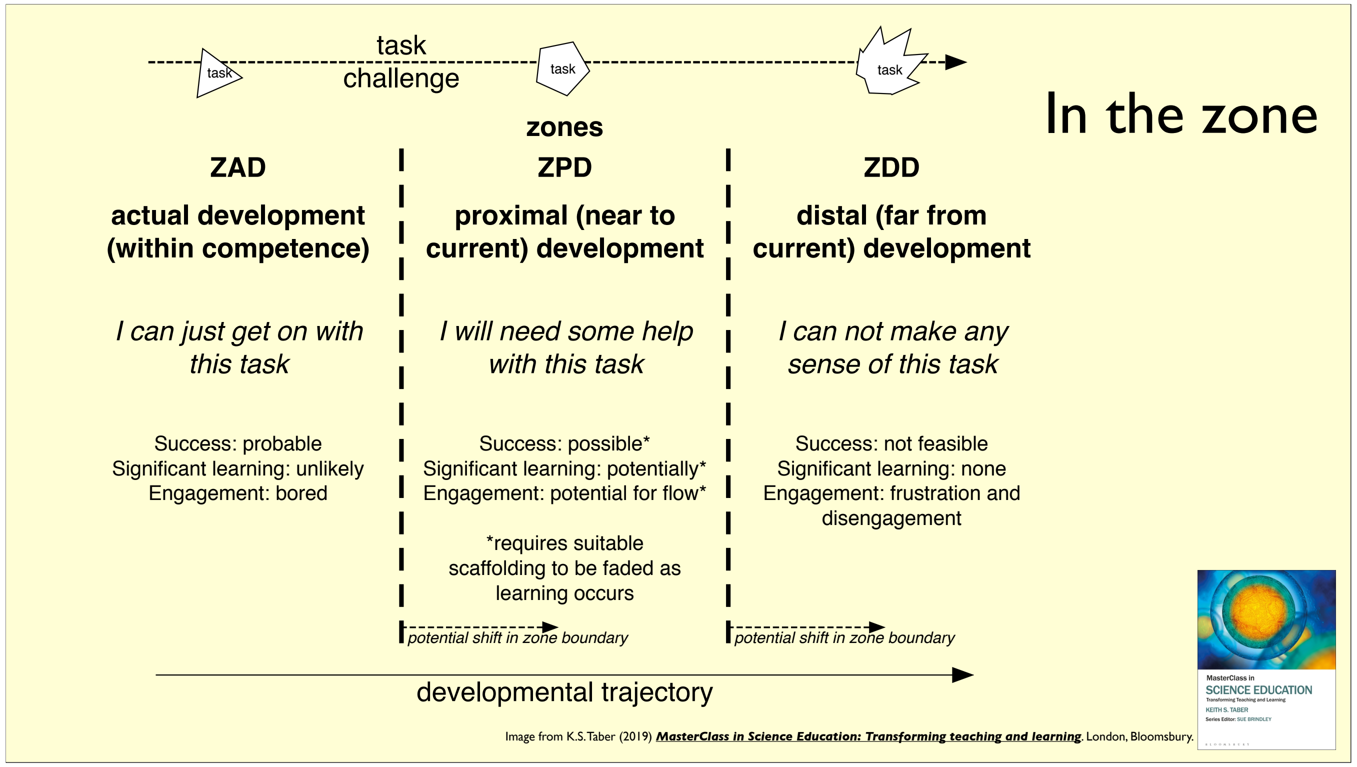
One zone reflects activity that the learner is fully capable of without any help. Work set in this zone can be completed well without any support from the teacher. We can imagine the classroom of learners all getting on with their own work and looking relaxed and untroubled, or the lecture room full of happy smiling faces clearly fully understanding everything they are being told - because what they are being told includes nothing substantially new to them.



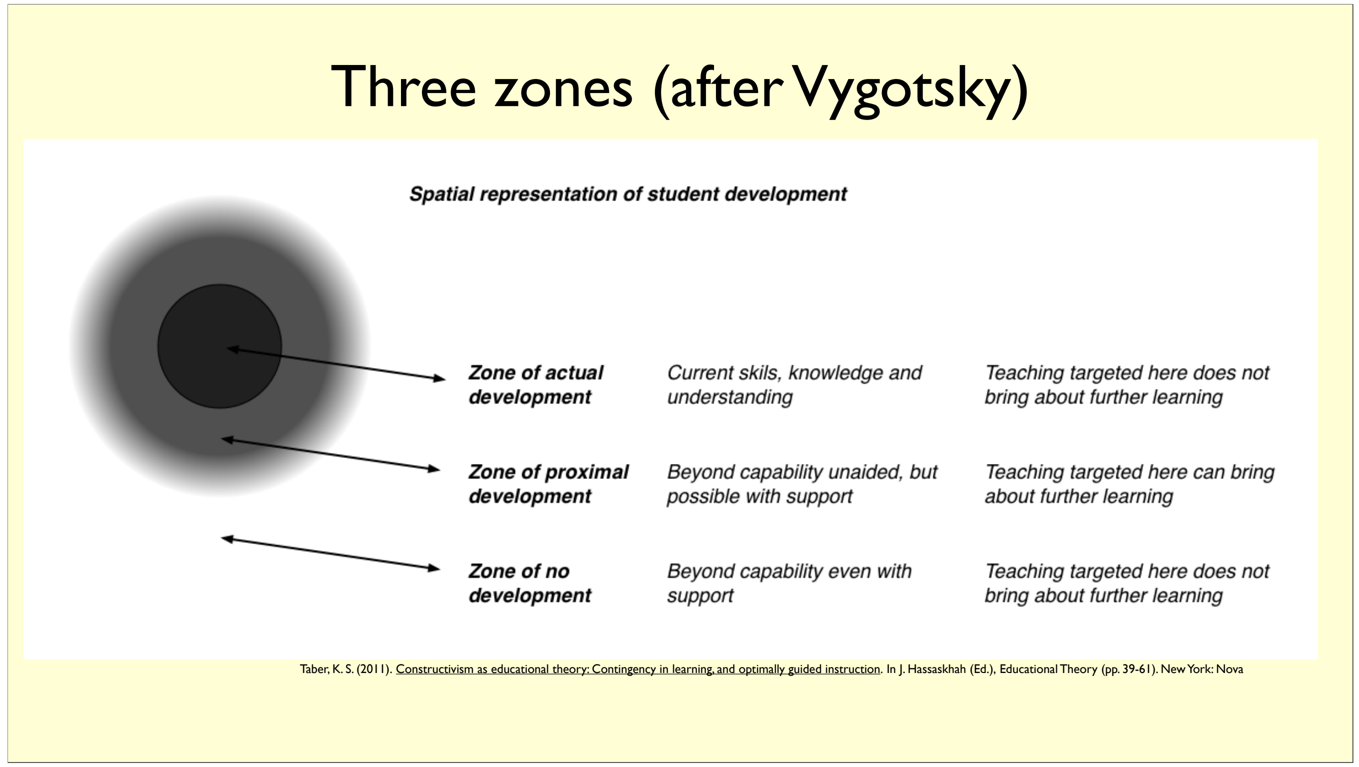
Work set in one of the other zones is quite different - here the student will not understand the task, will not have a clue what to do, and will be totally lost and likely frustrated. Students will not even be able to engage in the set tasks, or will be listening to a lecture much as if it is being spoken in an unfamiliar, foreign language. No learning will take place.



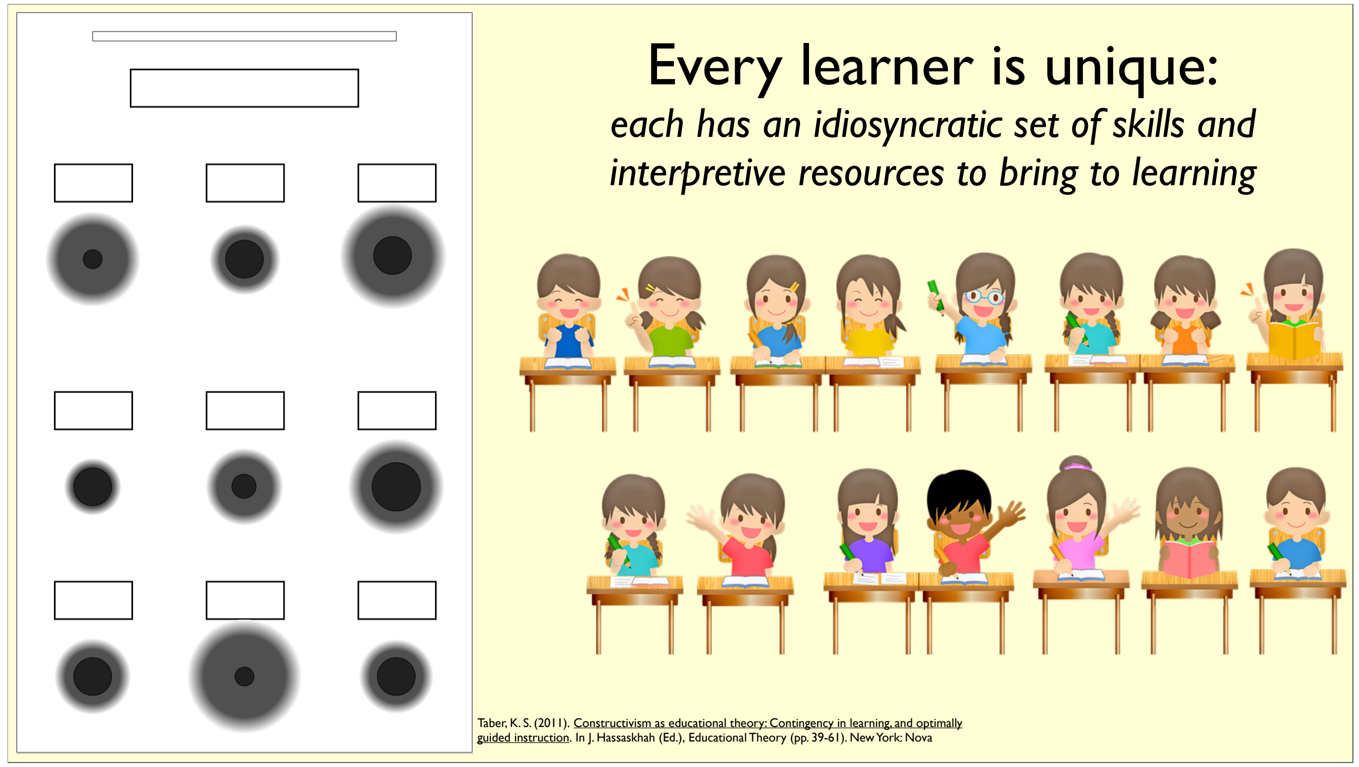
However, there is a third zone intermediate between these two. Here tasks will be designed, or presentations will be pitched, so that they again go beyond the current competence or knowledge of the learner, but such that learners can at least appreciate the challenge, and see how it relates to previous learning. In this zone, students are not ready to complete the work unaided, but they can start to make progress when given some clues, or help, or modelling.



Vygotsky's argument was that it was only in the intermediate zone, the so-called zone of proximal development, that students would be able to make the kind of progress we might call development rather than just practicing and finessing their existing accomplishments. So, as with so much in life, we need to choose the option that involves the right level of challenge for both students and teacher if we want to get the most out of the experience.



So the teacher needs to set challenging learning activities, but also provide support. Support that allows a student to make progress in the zone is known as scaffolding. Over time the students will achieve mastery and no longer need the support. Then we have slipped back into that first zone, and it is time to increase the challenge a little more.



Now there is a very big complication, of course, which is that every learner is unique. Locating a task in one student's construction zone often makes that task much too easy for another student to genuinely challenge them, and yet out of reach for another such that they are not ready to engage with it even with modest scaffolding.

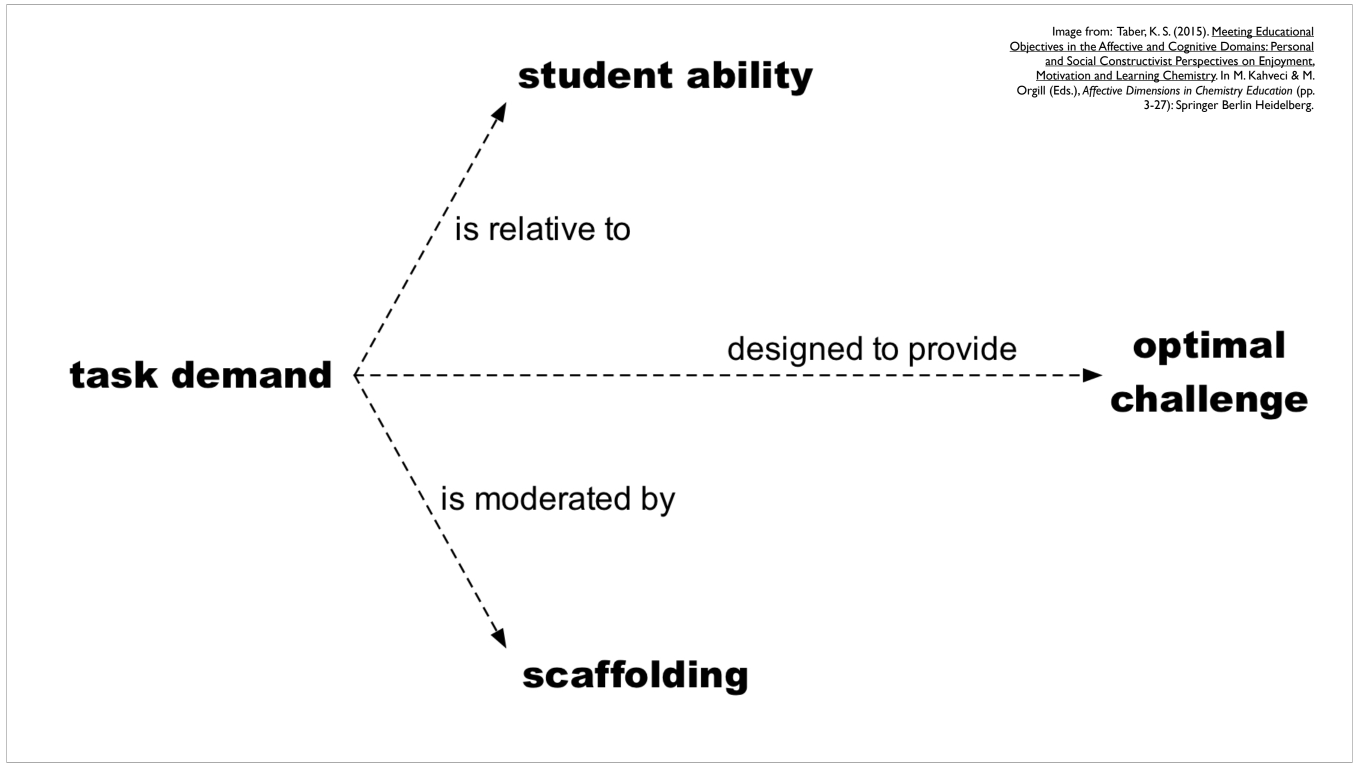
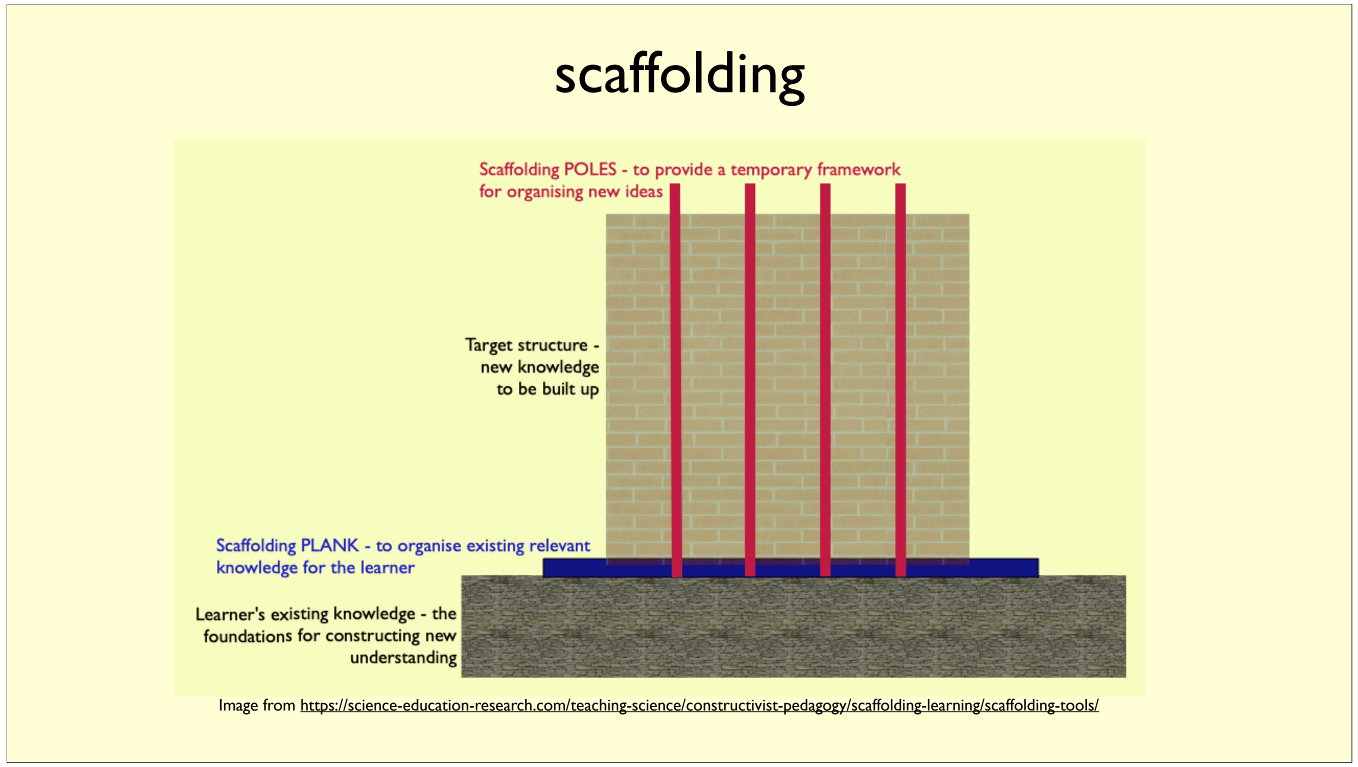


Image from: Taber, K. S. (2015). Meeting Educational Objectives in the Affective and Cognitive Domains: Personal and Social Constructivist Perspectives on Enjoyment, Motivation and Learning Chemistry. In M. Kahveci & M. Orgill (Eds.), *Affective Dimensions in Chemistry Education* (pp. 3-27): Springer Berlin Heidelberg.

There is not an easy solution. Personalised learning may require unrealistic levels of teacher preparation time, and may lose the social cohesion within a class of students that feel they are moving along the same path together. Yet, simply aiming for some kind of median level leaves some behind and also fails to challenge the most advanced students and help them develop.

There can be a middle way using differentiation by support.



That is, learning activities are designed to be challenging for all but graduated levels of scaffolding are provided to support different learners in the class.

Scaffolding is intended to be temporary. It is provided whilst learners needs support and faded once they develop mastery.

https://science-education-research.com/teaching-science/constructivist-pedagogy/scaffolding-learning/

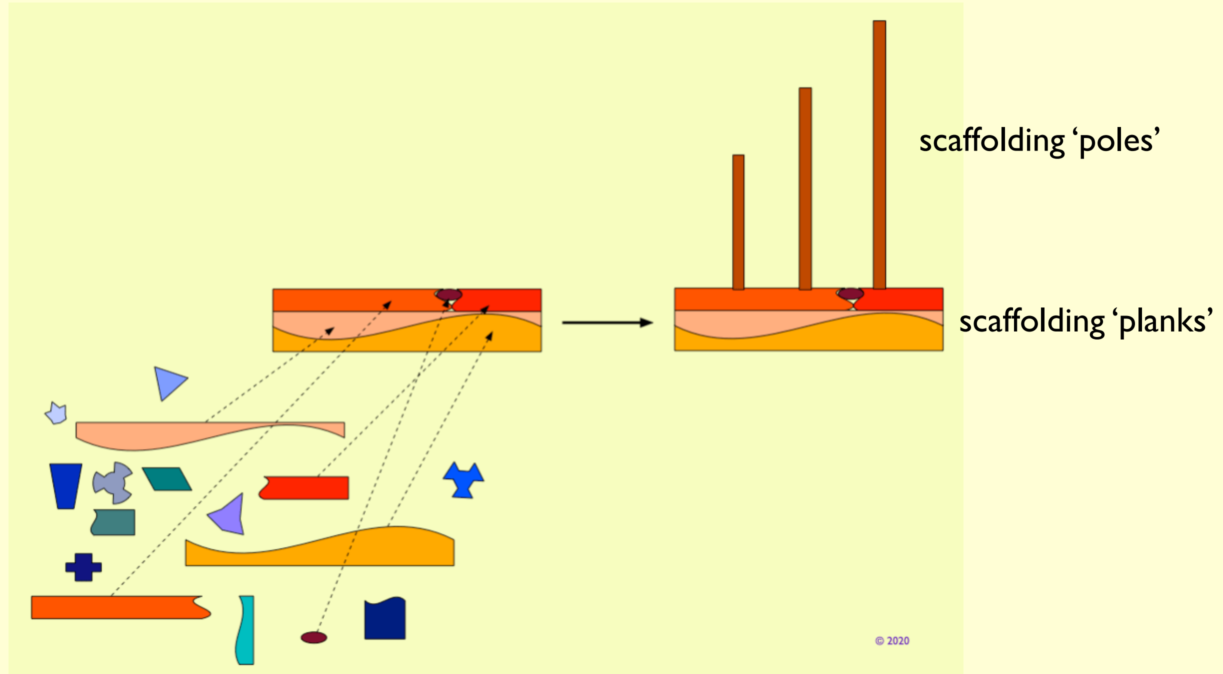
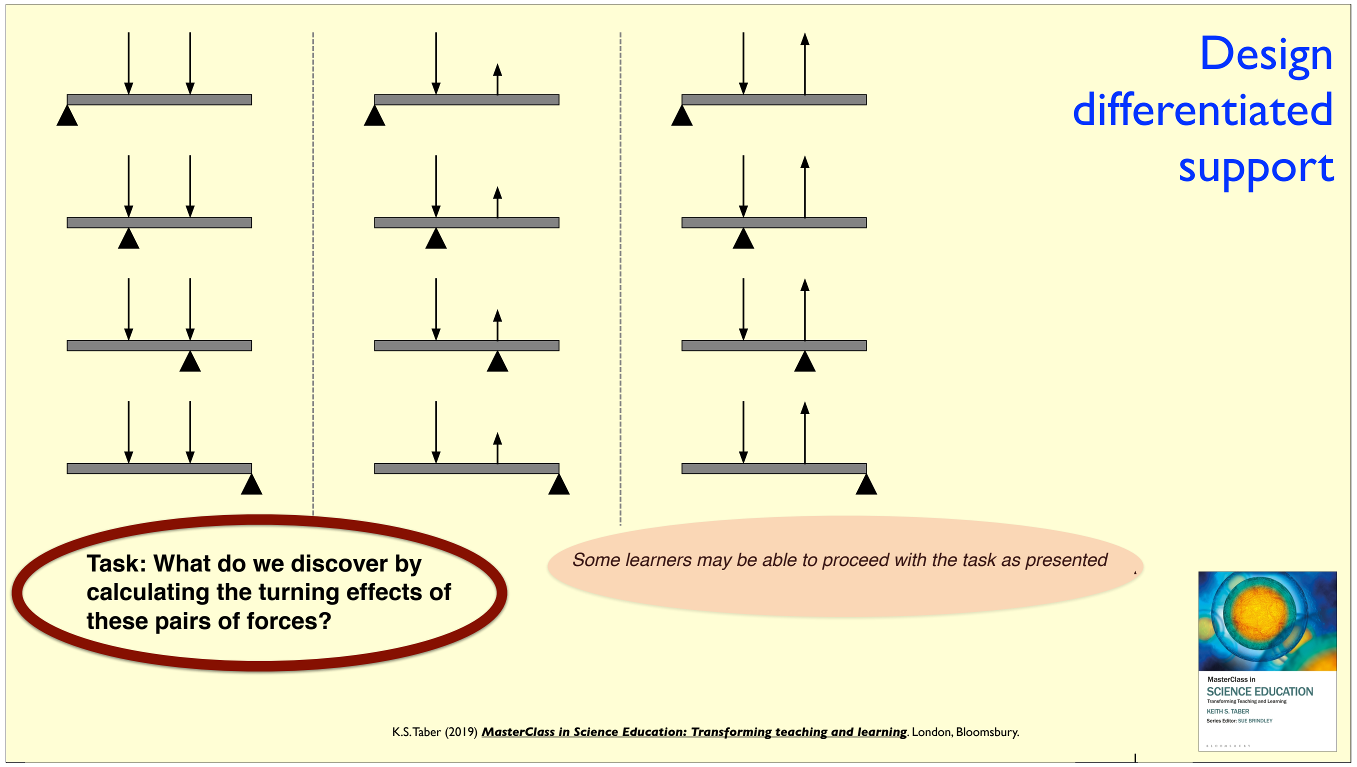
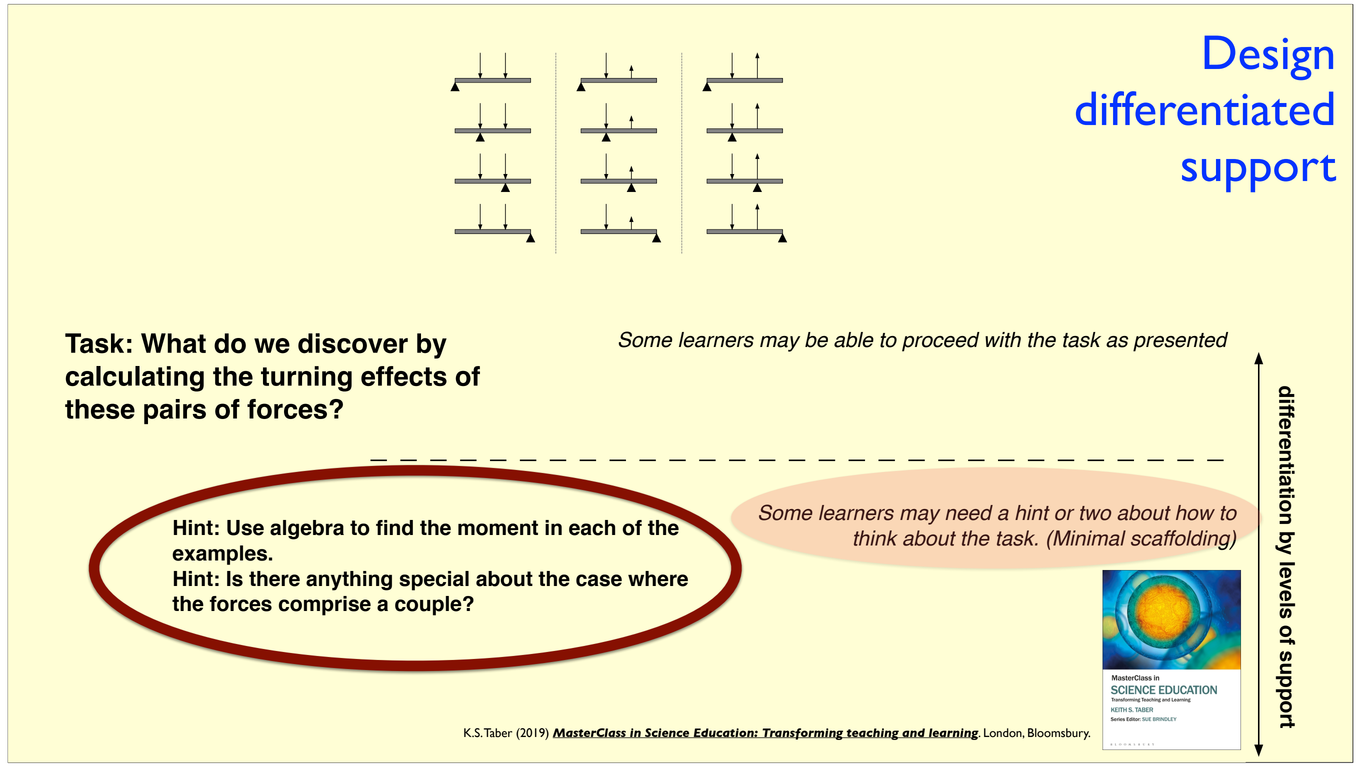


Image from https://science-education-research.com/teaching-science/constructivist-pedagogy/scaffolding-learning/scaffolding-tools/

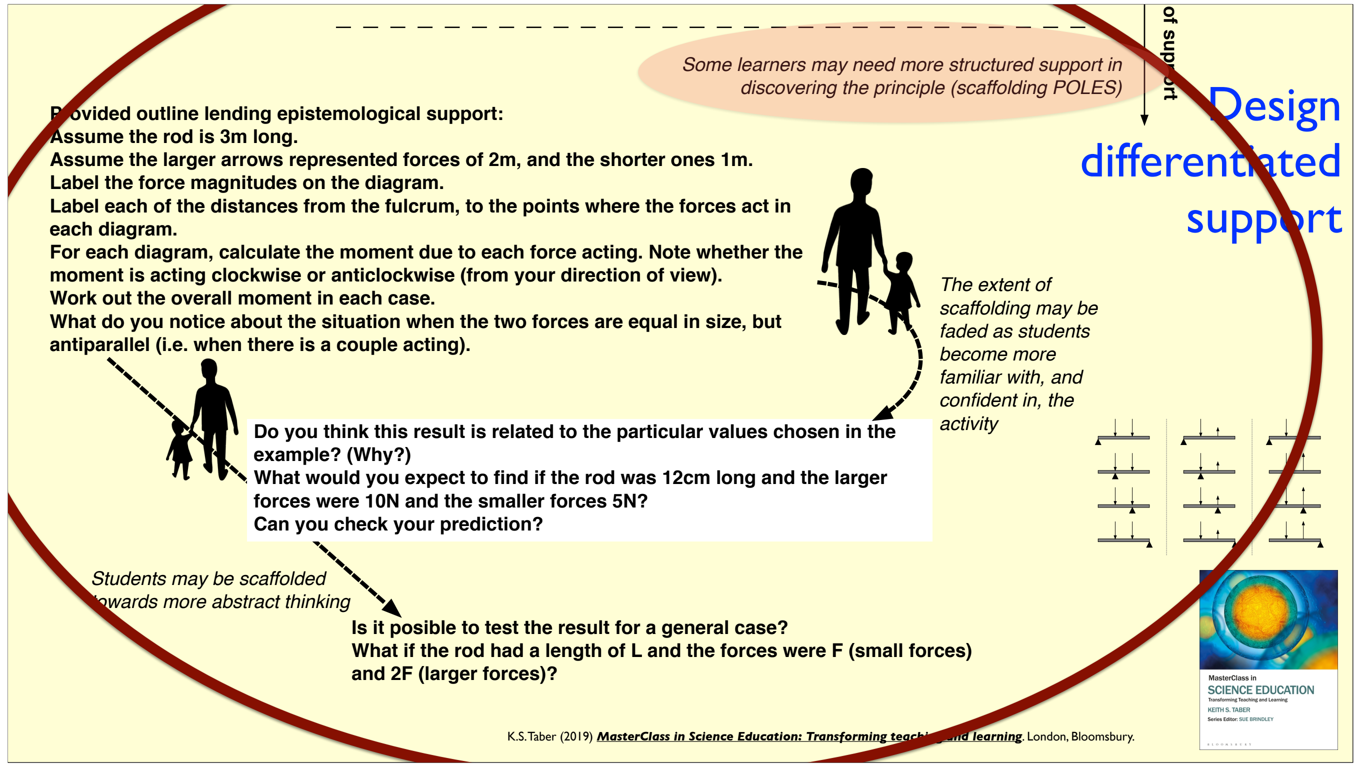
The metaphor of scaffolding poles refers to support provided by the teacher to help the learners reach beyond their current level of mastery. As in building a house, once the construction is completed the scaffolding will no longer be needed.



Here is an illustrative example of a task which is designed to allow students to appreciate a scientific principle through guided discovery.

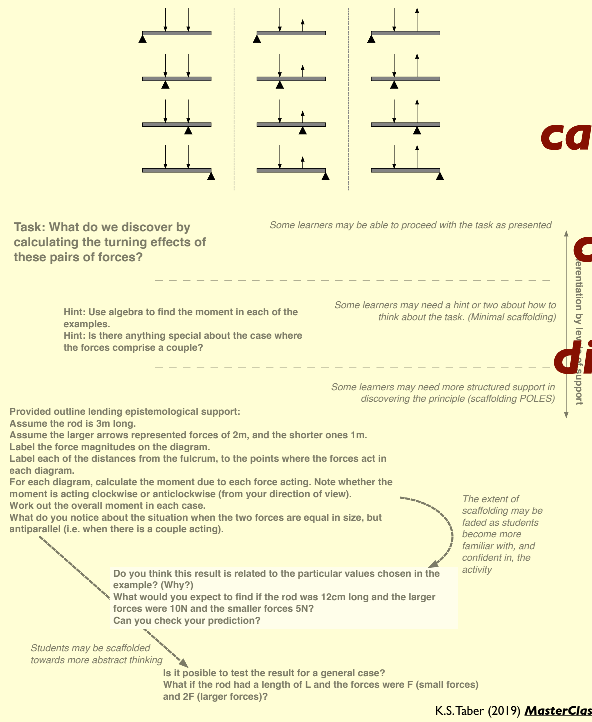


Some learners may need a few hints to set them off in the right direction.

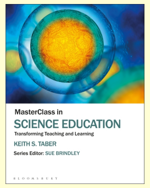


Others may need a lot more hand-holding to guide them through the activity.

Design differentiated support

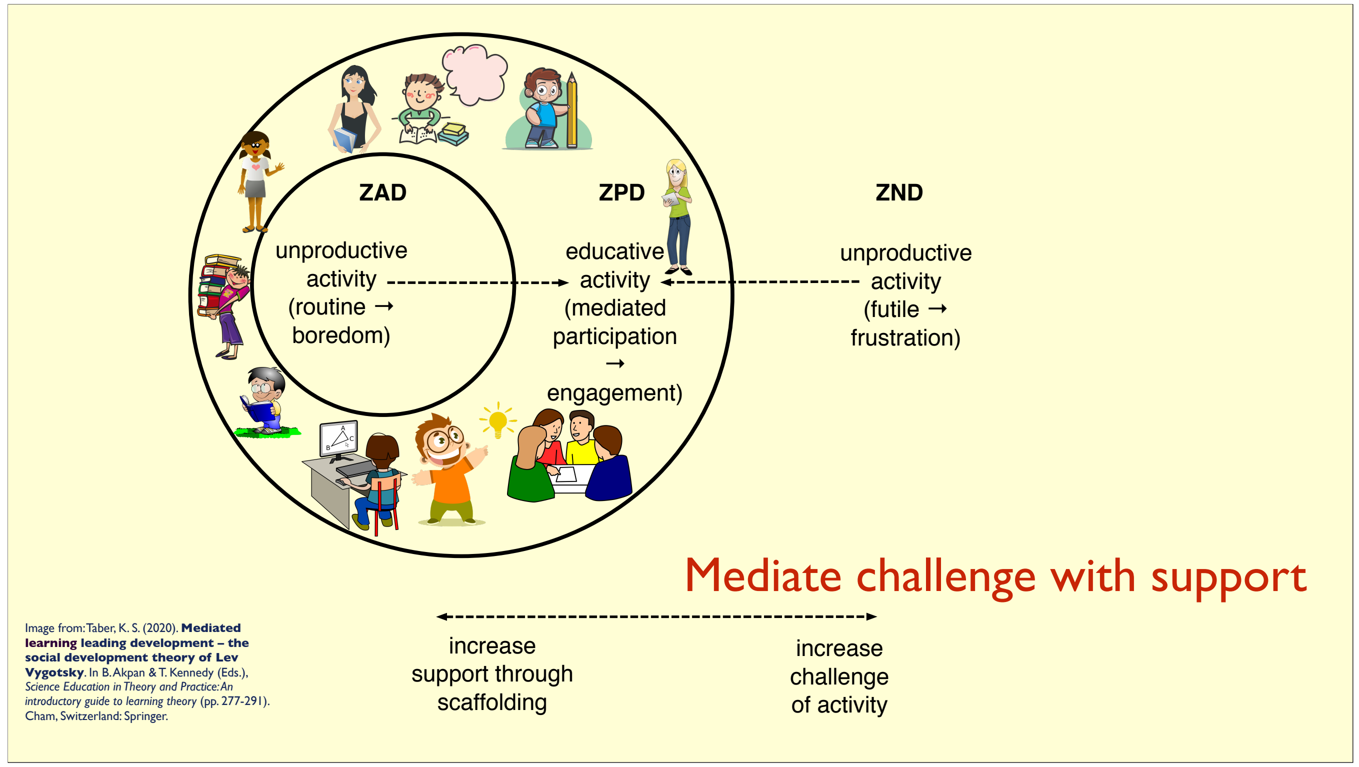


can you think of examples from your discipline / curriculum area of how you might offer differentiated support to structure the same challenging task with different levels of support?



K.S.Taber (2019) ***MasterClass in Science Education: Transforming teaching and learning***. London, Bloomsbury.

Often it may be possible to encourage group work where students mediate each other's learning. It is certainly not right to ***require*** more advanced students to act as tutors for benefit of the classmates - but we all know that teaching, and preparing to teach, are incredibly powerful learning activities, so it may be possible to design roles for some learners to support the learning of others in ways that benefit both parties. This can be in direct face-to-face work or helping develop learning support materials.



It is also possible to set mini-projects with differentiated roles and responsibilities, such that although a team has a common task, it can be broken down in ways that mean everybody is being stretched, yet also enabled by the support available.

My final slogan relates to the nature of long-term memory.

We do not know exactly how the mechanisms of memory work, but there is a lot of research on how memory functions.

What is memory?

a quick memory test!

If you viewed the previous lecture you may remember some of the things said about memory there?

What is memory?

- A ***d*** function that influences perception.
- Memories are c over time, and can become integrated - they are ***m*** whenever activated.
- Experience cannot be stored, only ***r*** .
- Remembering is a process of ***r*** informed by memory traces.

What is memory?

- 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.

Memory:

Temporary - may or may not lead to a…

Permanent representation - may or may not be integrated into web of representations

May later be activated, strengthened, modified, become conflated…

There seems to be at least three stages of memorising once material is no longer in working memory with its very restricted capacity. Our initial memories of daily experience are only retained in a temporary and fragile form. If normal functioning is interrupted - by the bang on the head so beloved of fiction writers - we can suffer amnesia, and all those temporary memories are lost.

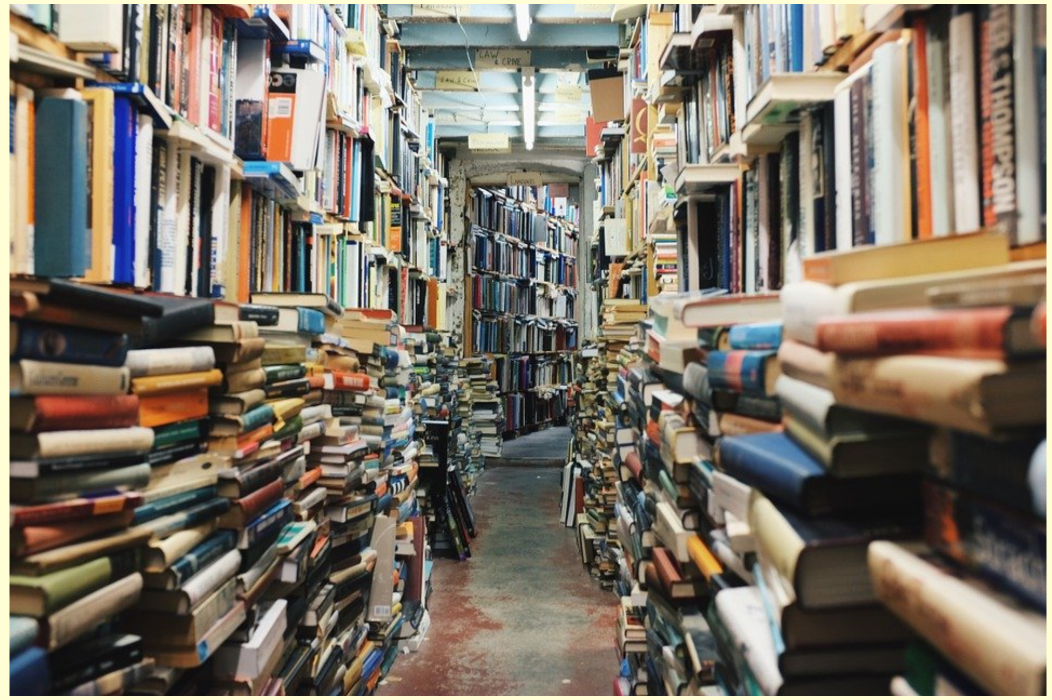
Memory:

Temporary - may or may not lead to a…

Permanent representation - may or may not be integrated into web of representations

May later be activated, strengthened, modified, become conflated…

The second stage occurs some hours later when some kind of permanent trace is made in the brain, presumably in terms of changes in connections in synapses, which, when subsequently activated allow us to remember something.



These traces are provided with a temporary means of access, a bit like new books arriving in a library or book shop being initially simply classified as ‘new stock’.

Memory:

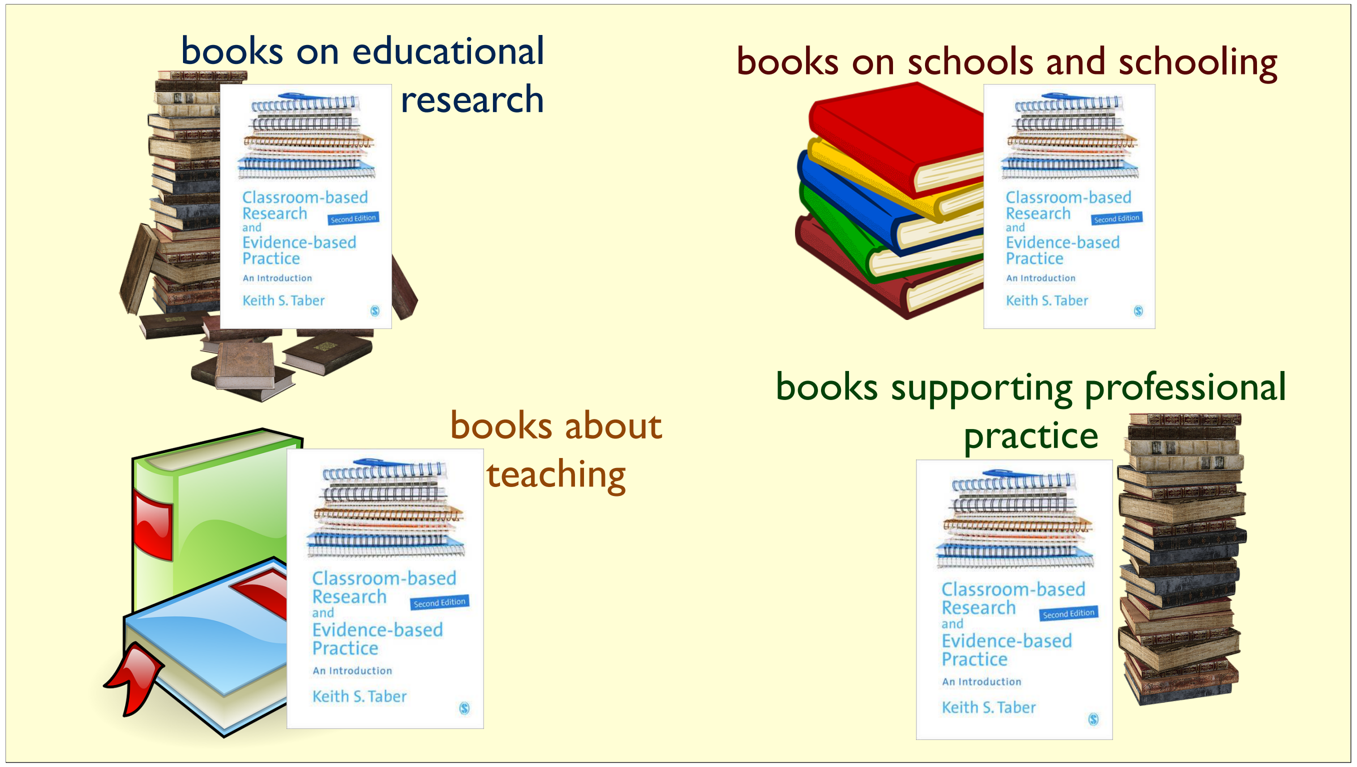
Temporary - may or may not lead to a…

Permanent representation - may or may not be integrated into web of representations

May later be activated, strengthened, modified, become conflated…

The third stage is typically something that begins over a period of days, which is the activation of these new memories, and their linking with other material represented in memory.

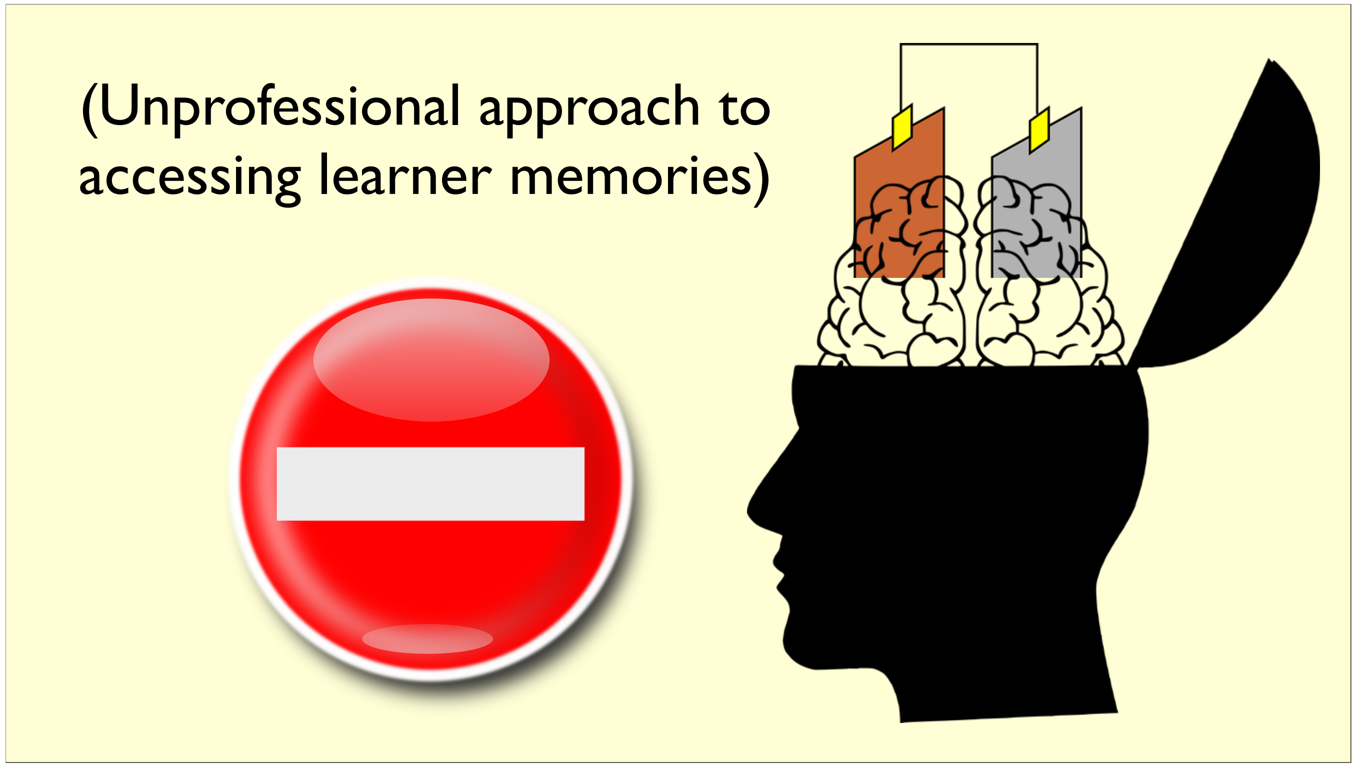
In the analogy, our librarian picks up the book from the pile of new stock, identifies its catalogue number and moves the book to the correct section of the library.
But memory representations do not have any inherent catalogue numbers, and are not physically moved but rather are given new connections - so it is more like the new book being connected by strings to other related books. This seems more messy, but has the advantage that potentially we can link this new memory with several existing representations rather than having to put it on a single shelf.



So, this is actually more like a publisher's website where you may notice the same book is often listed under several different headings. The more listings a book has, the more readily it will be found by potential customers.

Many of the books that arrive never get catalogued in this way, and end up in a disordered pile as they get displaced.

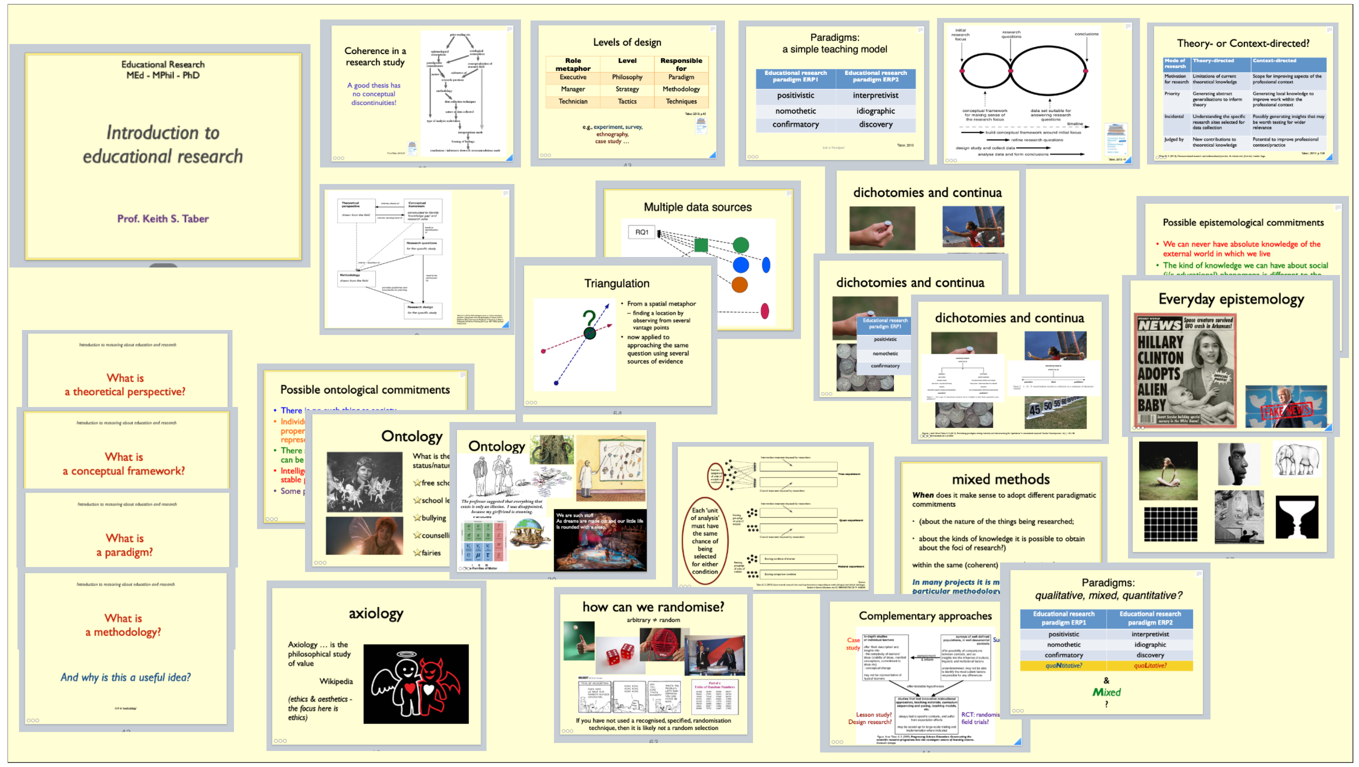
Most memories are effectively lost in the system.



Interestingly, brain surgeons who work on conscious patients to probe brain areas before removing diseased tissue, report that sometimes electrical stimulation activates a memory that a person had not experienced for decades, but this approach is not usually considered appropriate in teaching,

So something that we have been told in a lesson or lecture, may never be represented in memory. If it is, and that memory trace is not activated on the days immediately following, then it is likely to be just another lost volume, out of sight, and out of mind. This is why students should always start reviewing their class notes within a few days of any lesson or class.

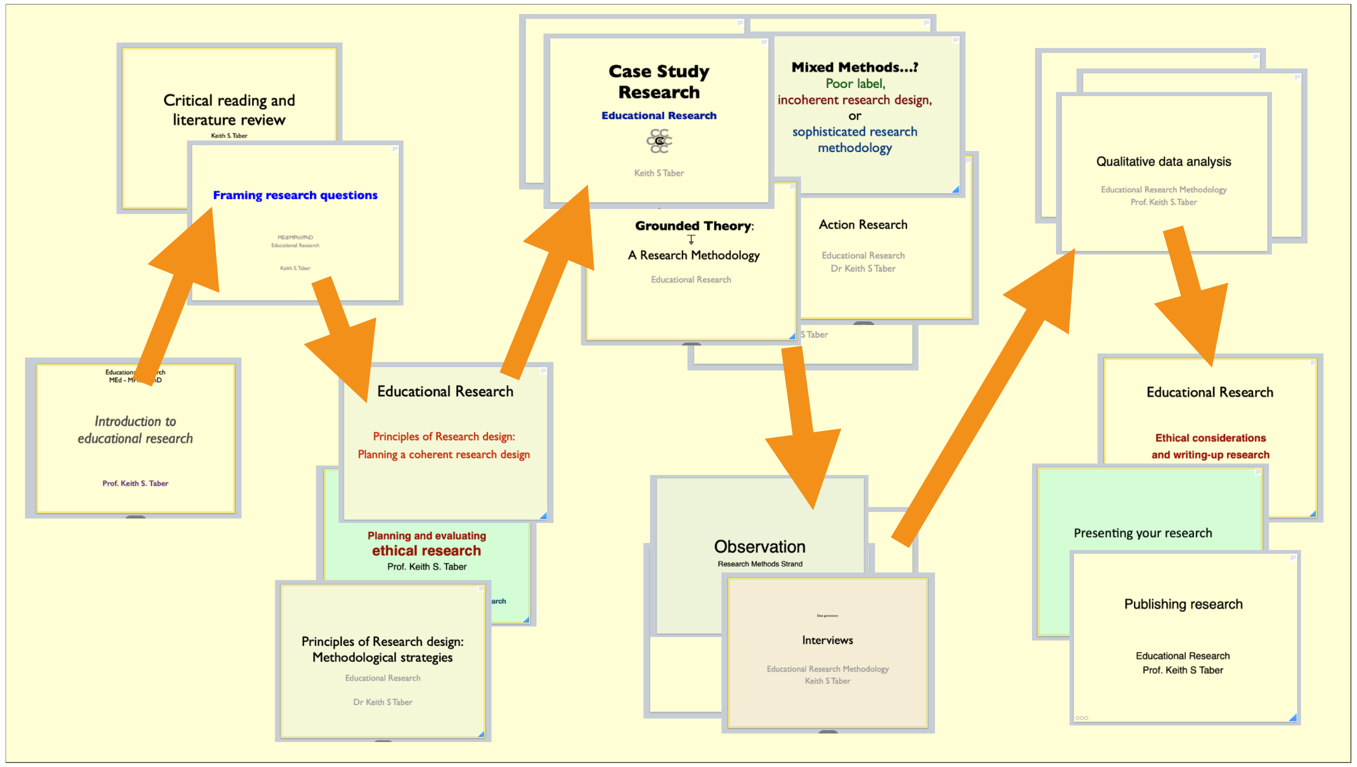
When recent learning is regularly reviewed and applied in different contexts it becomes embedded in a network of connections and is more readily recalled.
Teachers can support the process of reinforcing and consolidating learning.



You should identify the key ideas and principles and themes in a course, and introduce these as early as possible in the programme.

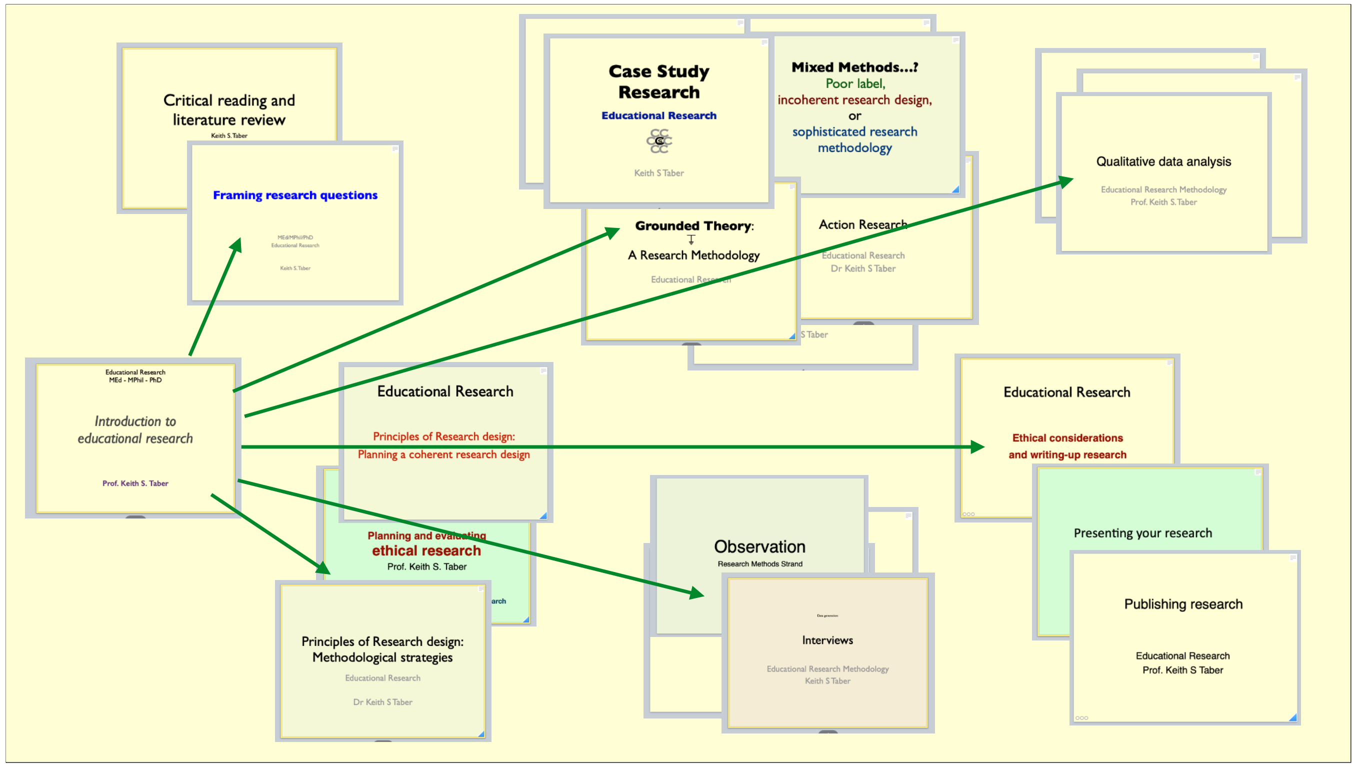
When asked to teach an introductory lecture for a course I looked to include key concepts and terminology that students would meet during the course. It was made very clear that all these ideas would be picked up during the course and it was not expected they would remember everything from the introductory lecture.

https://science-education-research.com/research-methodology/



Students were told that this was intended to give an overview of the territory of the course, and the route they would take through it.

When planning your classes you then look for every opportunity to highlight and review what has been previously taught, and indeed to drop in tasters (or perhaps teasers) as preparation for teaching to come.



You identify key concepts, principles, technical terms, and so forth and you look for every opportunity to see how they link between class sessions. You then ask students to make the links:

Can you recall where you have met this idea before?

Do you remember the term we used to describe this?

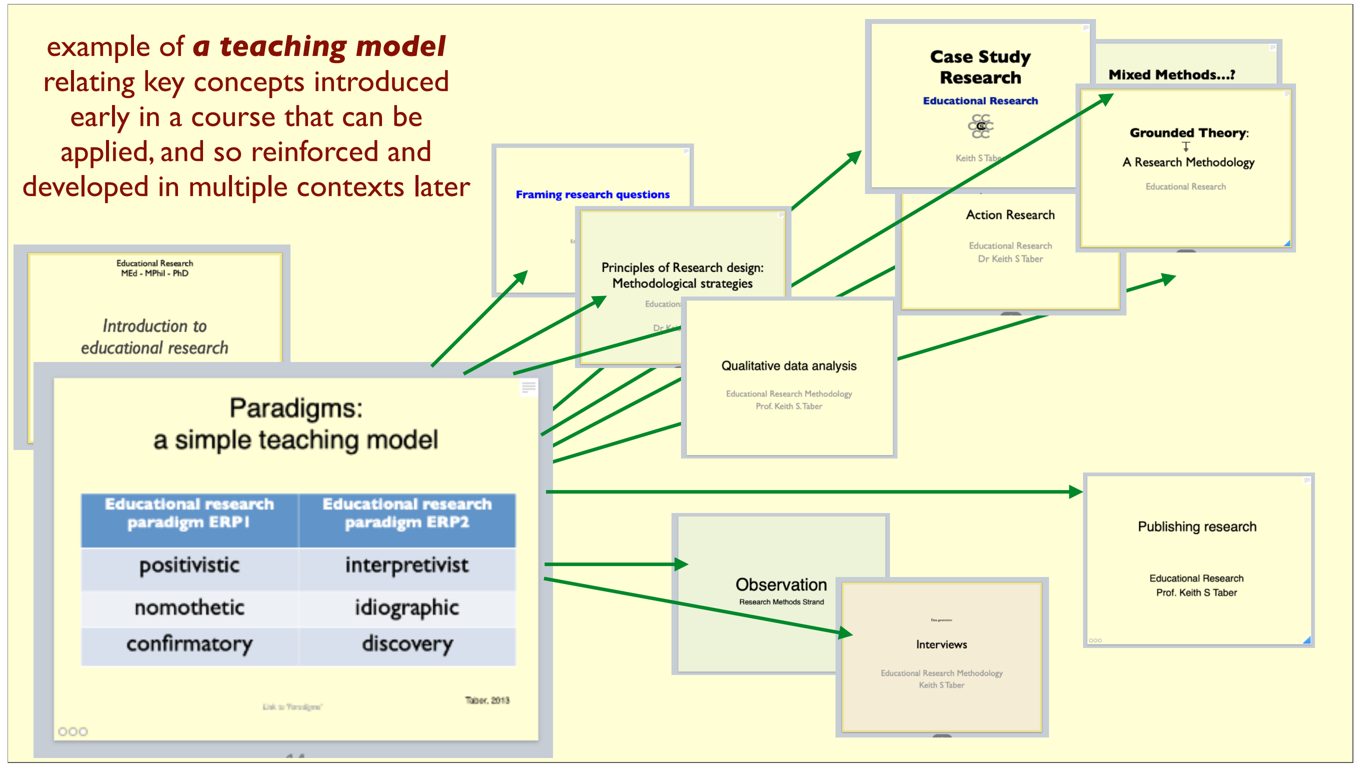
Can you see any principle we would expect to apply here? (How might it apply?)

This might be an example of something we discussed before - can you remember…

Do you think this idea might apply to any examples we have met in previous classes? (Which ones, why, how?)

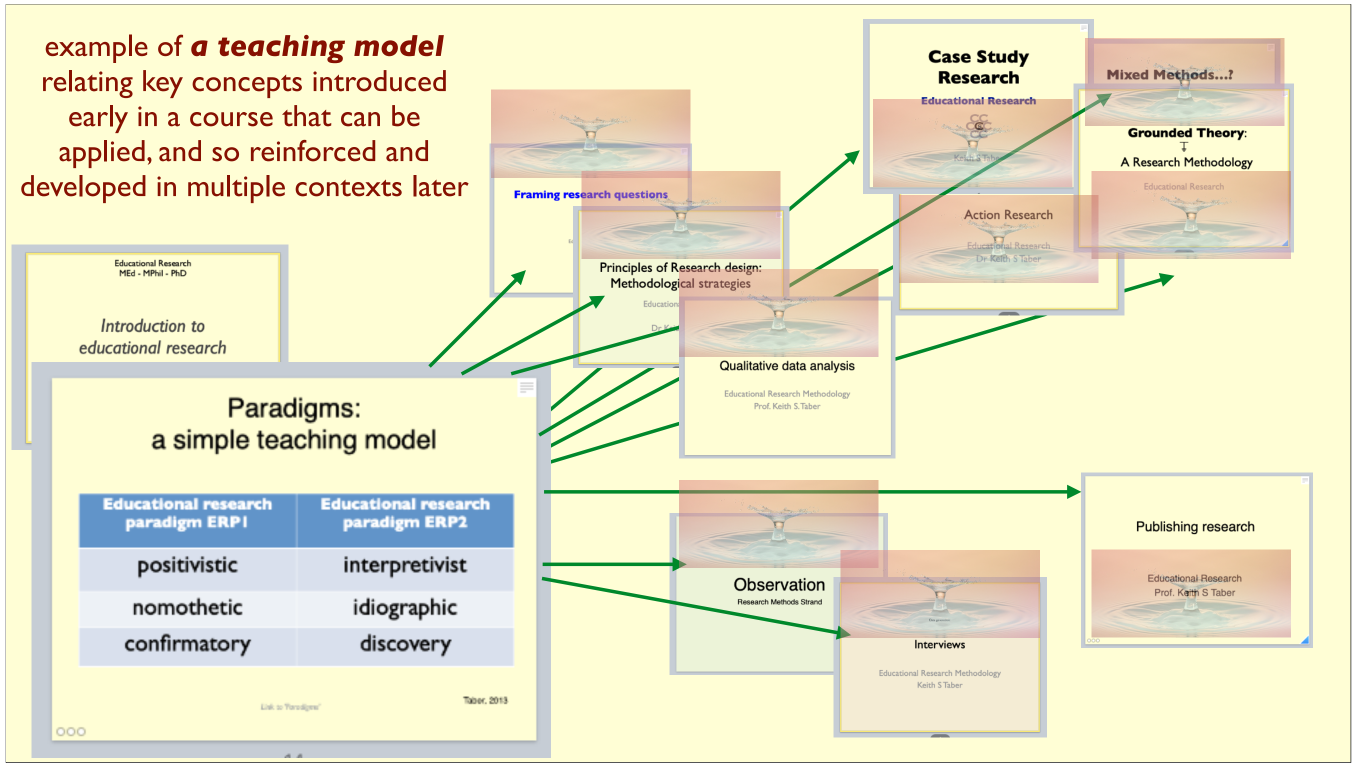
How might this fit with the model / typology / scheme … we met when we talked about about…

Does this fit with X's principle of/ theory of … (why do you think…?)

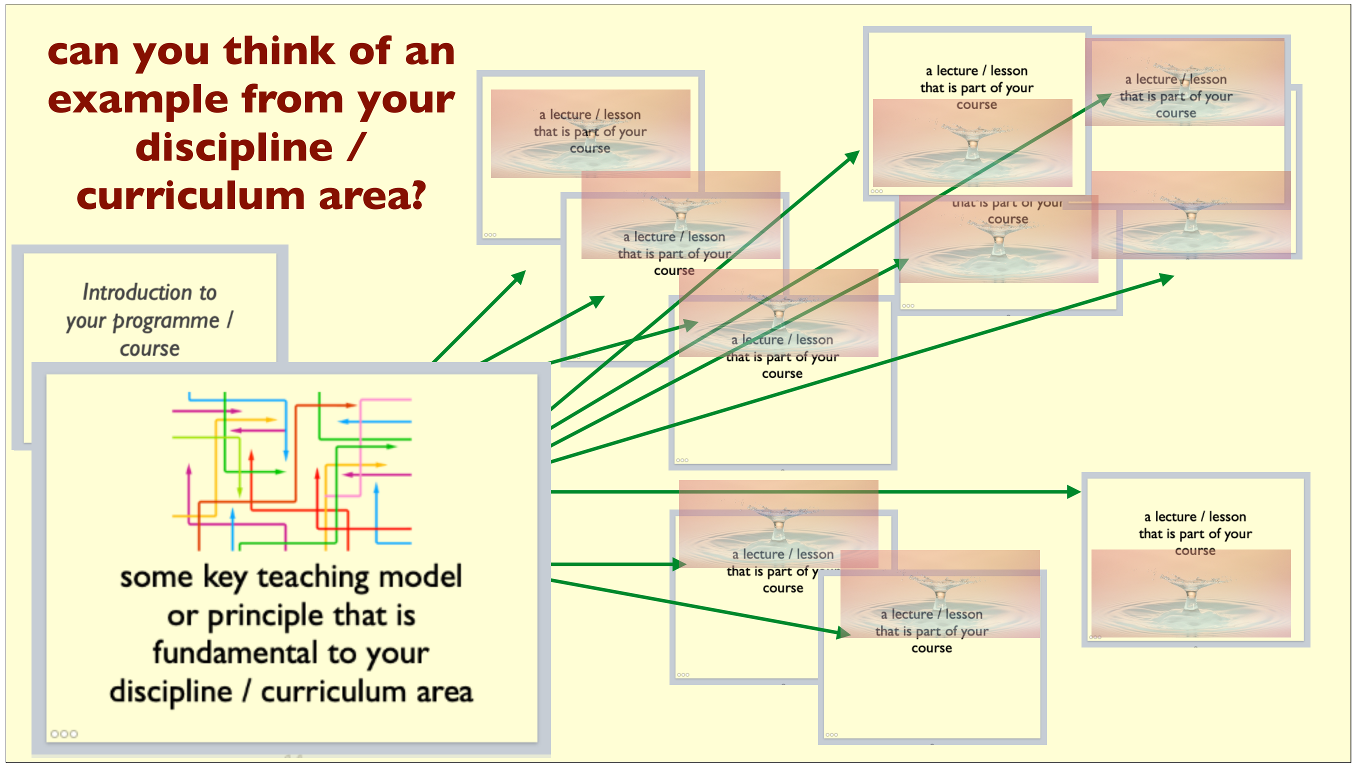


School teachers often do this as a matter of course, but it may seem an awkward thing to do in a lecture to adult students. Yet it is quite possible to build this approach into a lecture by briefly revisiting slides, or images or definitions etc., from previous classes at any point where you might be hoping learners will be linking back to these ideas.

As one example, here is a simple teaching model of an idea that some students find very abstract and difficult to link to their own research projects in a meaningful way.



This was introduced early, and then revisited in a wide range of contexts later where the prior learning was both reinforced and extended through new applications, and where the now familiar model also helped anchor learning about new topics.



Earlier I suggested that although practice is important, there is a danger of too much class time being spent on exercises to practice a taught idea before moving on to something new. It is likely to both better support learning, and provide better engagement, if we avoid too much practice through repetitive exercises immediately after meeting an idea, and instead look to challenge students to frequently review ideas at different times in different contexts.

S slogans for tremendous ?

‘make the unfamiliar, f ’

‘share the learner’s s point’

‘be a t , not a road map’

‘identify learning quanta at the resolution’

‘find the optimum level of s ’

‘mediate with support’

‘d reinforcement’

You can even reprise slides with modest changes to challenge learners to complete missing details.

Seven slogans for tremendous teachers?

‘*make the unfamiliar, familiar*’

‘*share the learner’s starting point*’

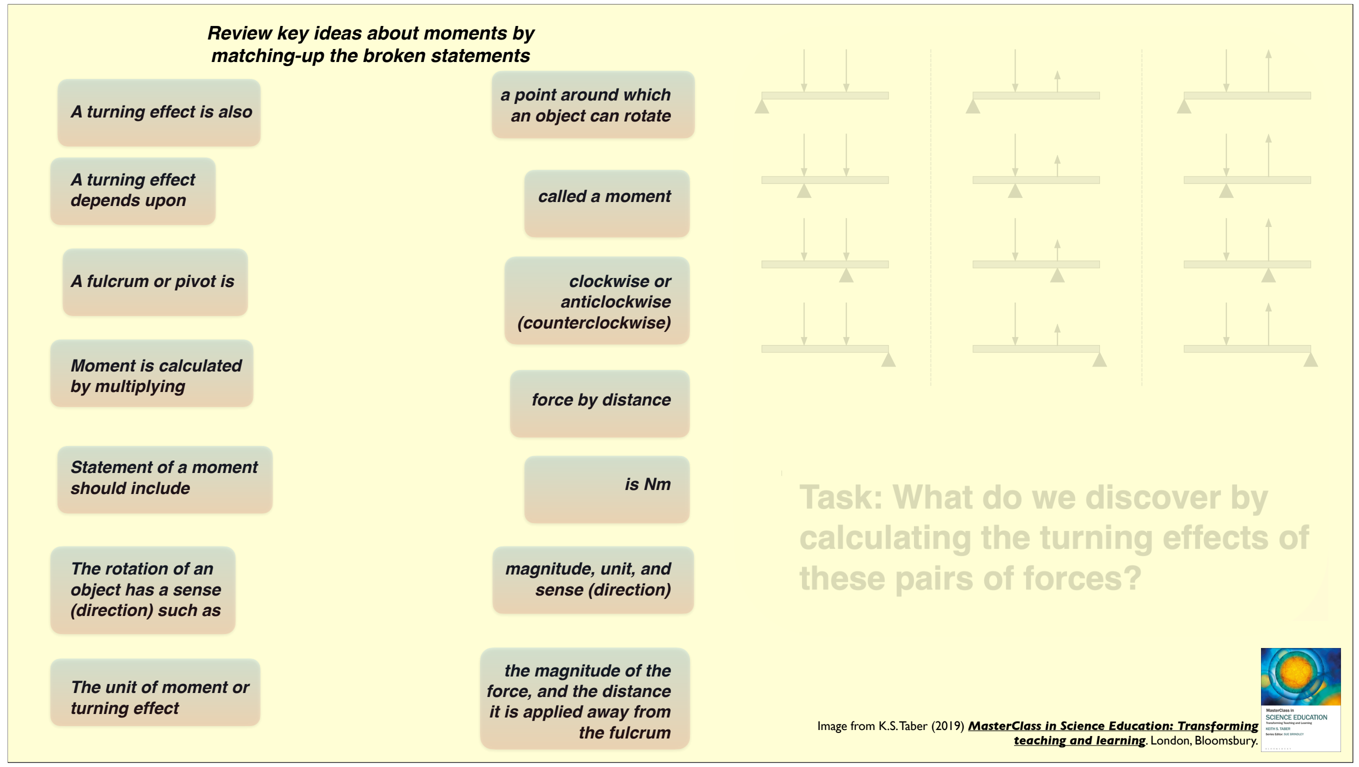
‘*be a tour guide, not a road map*’

‘*identify learning quanta at the learners’ resolution*’

‘*find the optimum level of simplification*’

‘*mediate challenge with support*’

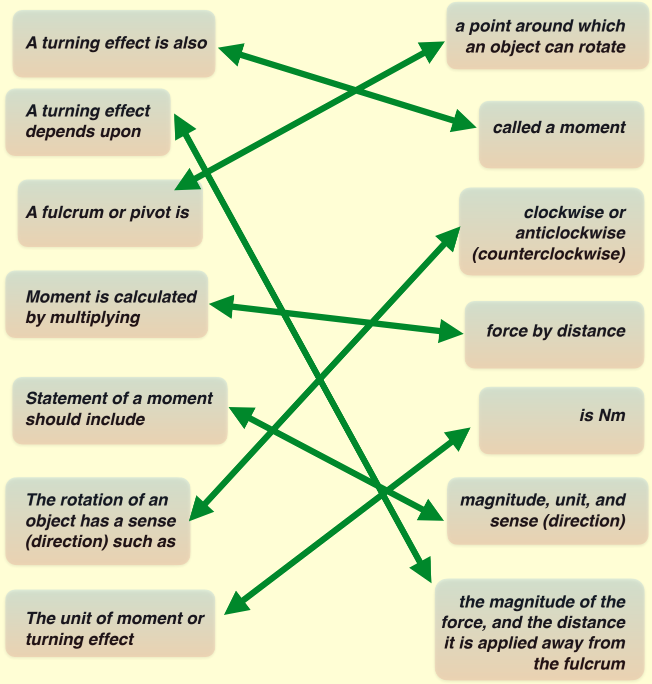
‘*drip-feed reinforcement*’

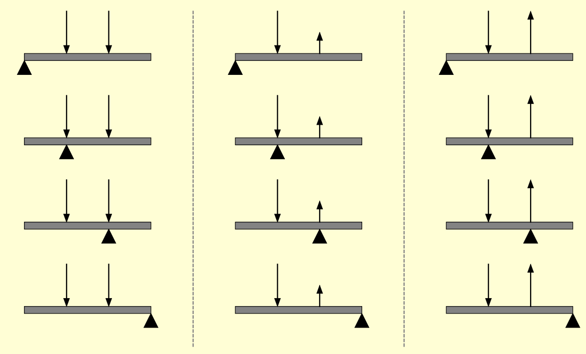


This idea of revisiting previous teaching also links with the idea of scaffolding. Whenever we introduce new ideas which build upon previous teaching we have to be aware that prior learning may not be readily brought to mind, and students may not be well placed to appreciate how prior learning is relevant to the new learning. This may not be obvious at the learner's resolution.

So before asking student to apply previous ideas in a new way, it is useful to give them a brief warm-up activity to simply revisit the ideas they are being asked to recall, and remind them of the key aspects that may be relevant to the new task.

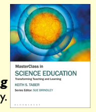
Review key ideas about moments by matching-up the broken statements

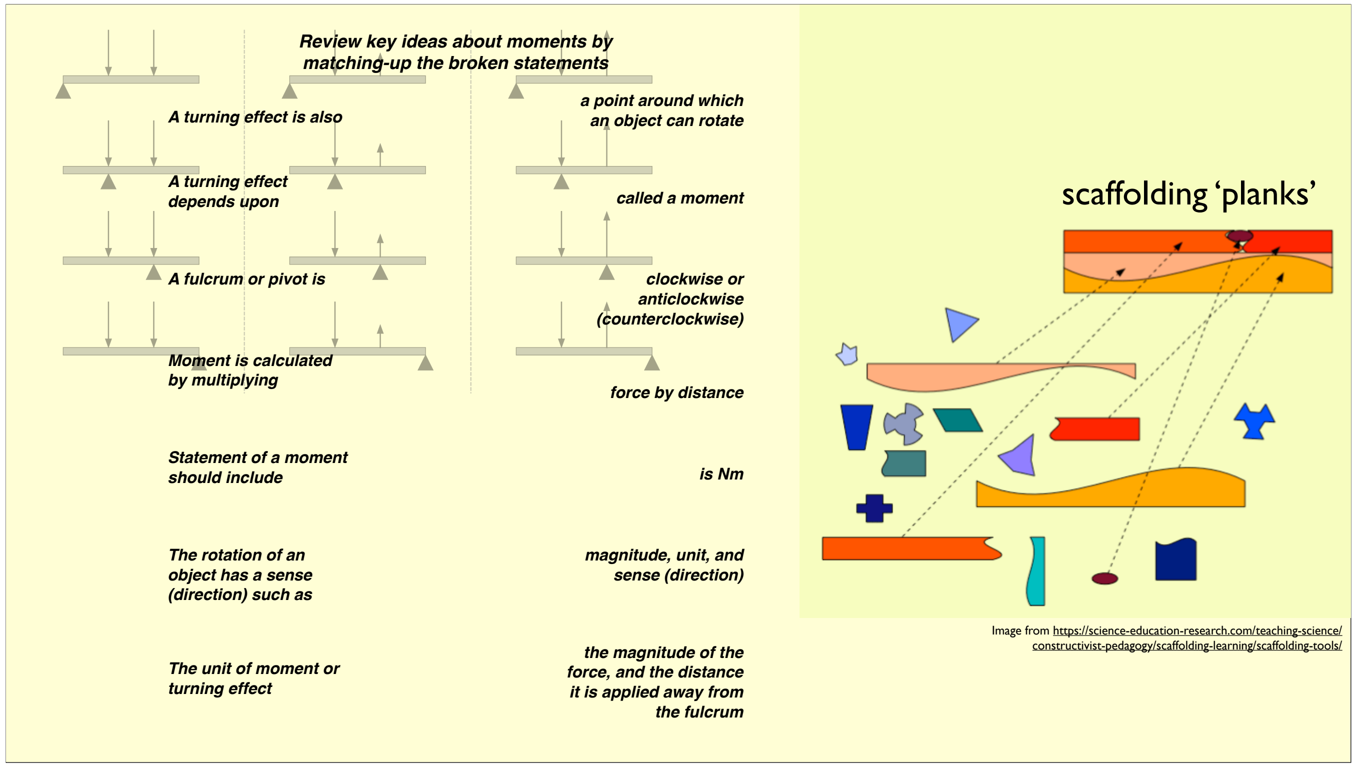




Task: What do we discover by calculating the turning effects of these pairs of forces?

Image from K.S. Taber (2019) ***MasterClass in Science Education: Transforming teaching and learning***. London, Bloomsbury.





We might think of this kind of activity as helping learners identify which prior knowledge we are asking them to use in a new task, and to remind them how it fits to together before applying it.

can you think of examples from your discipline / curriculum area

where it may be useful to offer students a simple exercise to help them recall and organise previous learning <u>before</u> they are asked to apply it in new learning?

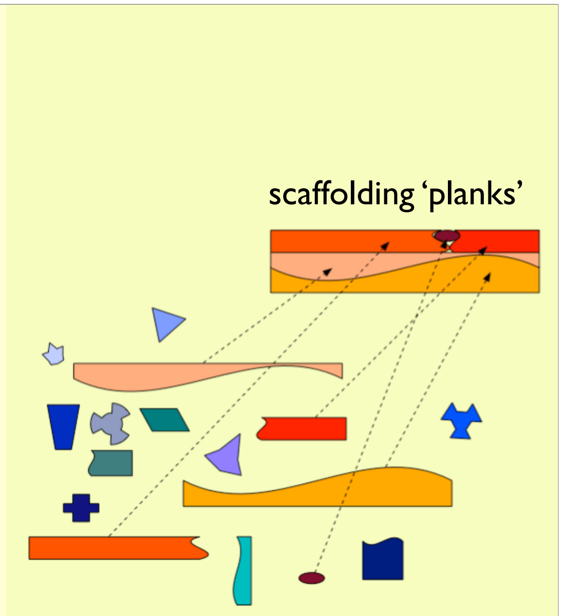


Image from https://science-education-research.com/teaching-science/constructivist-pedagogy/scaffolding-learning/scaffolding-tools/

This drip-feed teaching is not simply another label for the spiral curriculum. The spiral curriculum refers to designing teaching programmes such that complex ideas are met in increasingly sophisticated forms at different stages, so that the complexity can be built up as the learner develops. Typically the spiral turns once a year, or in some school systems, the same topic may only be met again after another two or three grades.

The principle of the spiral curriculum assumes that what is learnt in one turn will be available a year or so later to be developed, and without some extensive work to revisit and consolidate learning that is usually not going to be the case. Without deliberate and regular review, even if a student remembers having met the topic, any recalled details will likely be partial, vague, and distorted.

Memory is not really a place where we store things, but rather a representation like an image or symbol. So remembering is largely reconstructive - that is the brain has to construct the memory from a representation that is incomplete and open to interpretation.

Research suggests that sometimes students remember what they have been taught in lesson, but in a distorted form that might even be totally contrary to the original teaching. A memory that is not activated is a bit like a guitar or violin which has not been played - it will need retuning.

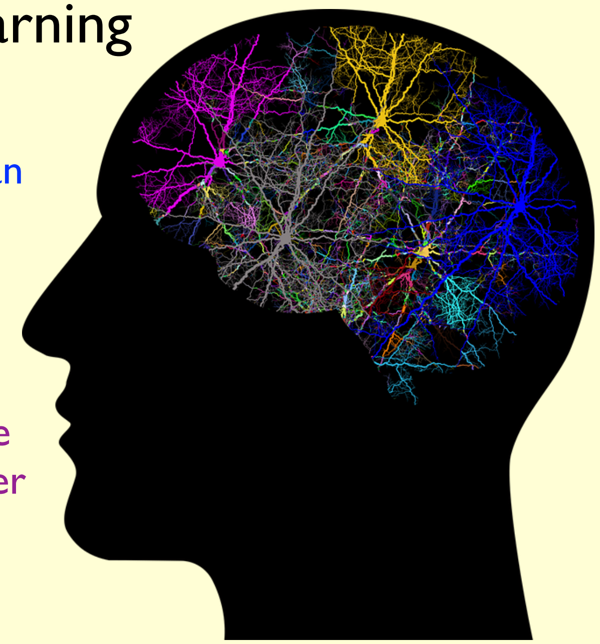
Each time we activate a memory we potentially modify it, which can be bad if the representation drifts from the original learning, but can be a good thing if we use the opportunity to not only reinforce the intended teaching but also to strengthen links.

I have attempted to design this lecture to build on what I said in the lecture on learning; and to have some links between recurring themes and motifs; and most of all to link with ideas, experiences, metaphors and images likely to be familiar to those listening.

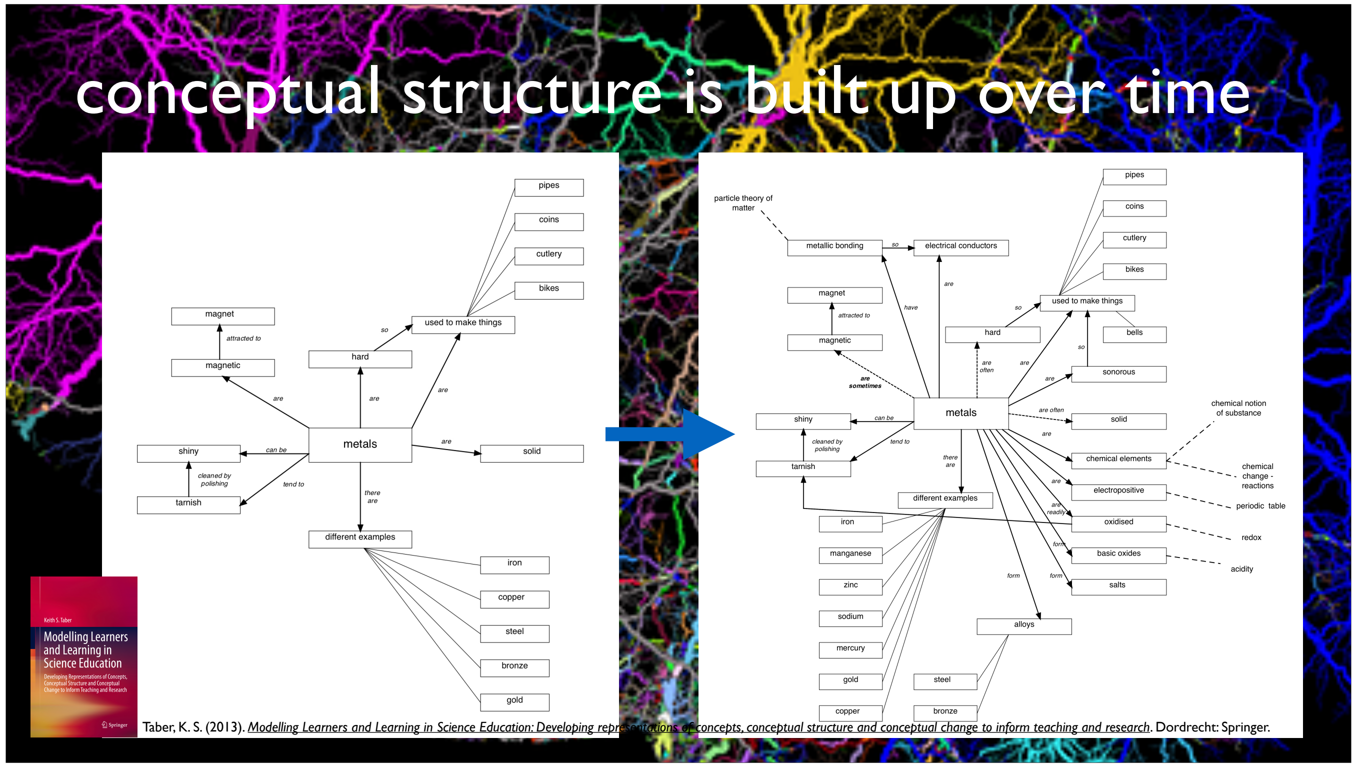
If I have failed, then I suspect your recall of the lecture will be something like my slide here - confused, partial, and not entirely accurate!

Regular reinforcement of learning

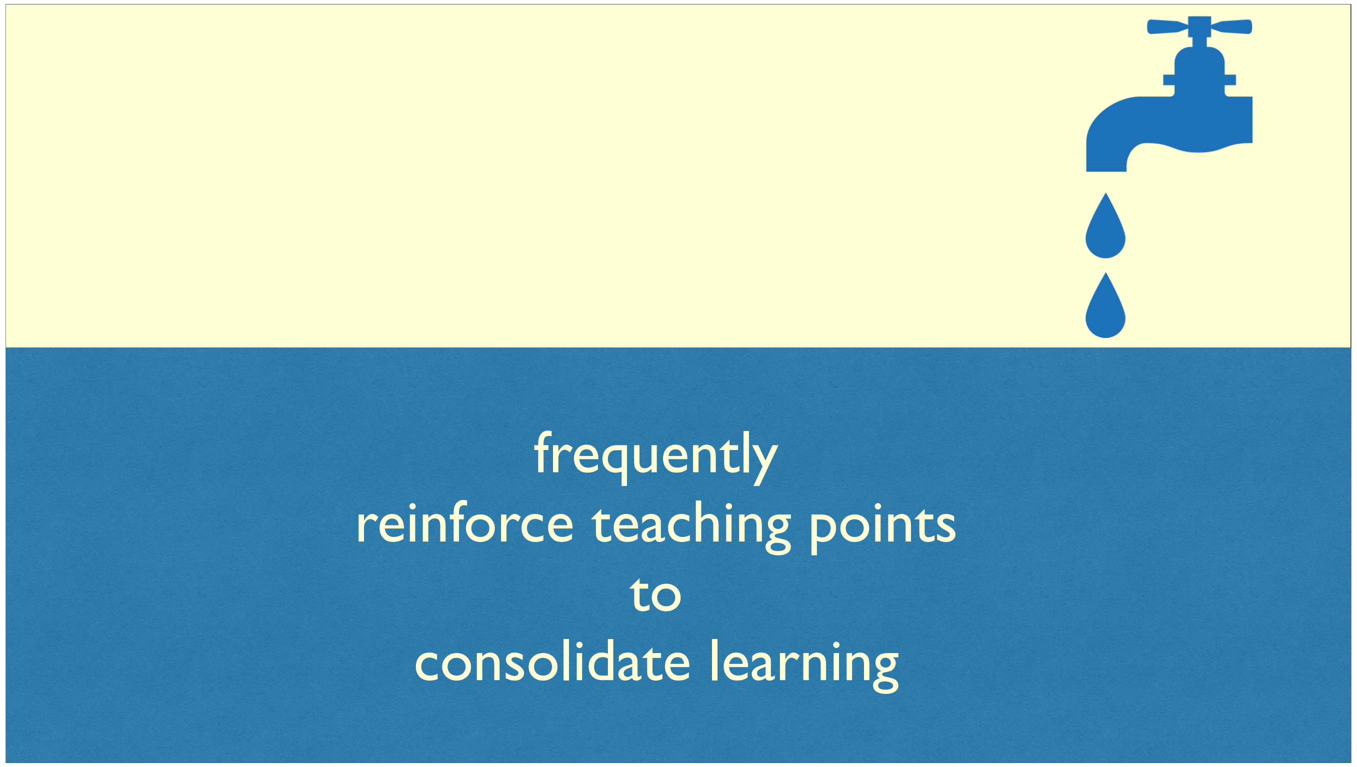
1. Makes later recall more easy to activate, so that what has been learnt can be more easily ‘brought to mind’;
2. Acts as a recalibration to help the learner reset their understanding to the canonical curriculum account;
3. Provides opportunities to build up the conceptual network by linking with other relevant concepts, and so to increase depth of understanding.



The teacher can reinforce recently introduced ideas so that they become integrated into memory, and then continue over the longer term to keep reviewing key ideas in the context of a constantly expanding web of meanings.



Constant encouragement to find and use examples and links between today's lesson and prior learning can support the process of developing more extensive and better integrated conceptual frameworks.



So this kind of constant drip-feed, ongoing review and practice of ideas, is what moves us towards expertise.

So in planning teaching programmes we need to consider two scales of structure - both the large scale progression of the spiral curriculum, and the drip-feed reinforcement that makes each stage of learning robust so it can act as the foundations for later development.

Seven slogans for tremendous teachers?

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'identify learning quanta at the learners' resolution'

'find the optimum level of simplification'

'mediate challenge with support'

'drip-feed reinforcement'

At the outset of this lecture I suggested that I would discuss some key aspects of the nature of teaching in accord with constructivist learning theory and represent these ideas as a series of slogans or mottoes. This is not intended to be condescending - rather I hope to have followed my own advice, and packed up these ideas in a way that makes them accessible to the audience, just as I am suggesting others do in their teaching.

Thank you

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