UNIVERSITY OF CAMBRIDGE


Faculty of Education

Conceptions of bonding

Keith S. Taber

Norwegian Chemical Society - Division for Chemistry Education
seminar at annual meeting, February 2023

Conceptions of Bonding
Seminar talk given to the annual meeting of the Norwegian Chemical Society - Division for Chemistry Education
February 2023

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Conceptions of bonding
a whistle-stop tour

1. Setting the scene: some examples of common alternative conceptions
2. The nature of chemical concepts and student conceptions
3. Origins/sources of learners' conceptions
4. The molecular (alternative conceptual) framework for ionic bonding
5. The octet framework explains alternative conception related to bonding, reactions, ionisation, chemical stability…
6. Teaching to avoid misconceptions

In this short talk I want to discuss something of the nature of student conceptions, taking as a focus the topic of chemical bonding.
This will be more akin to viewing the scenery as if from a passing train or coach, rather than having the leisure to stroll around a town and spend time examining the sights in any depth. But I do hope the talk will resonate with your own teaching experiences and be of some interest. I should point out that my own work has been largely undertaken in England, which raises the question of how this relates to the Norwegian context.

I am going to start by setting the scene by just putting up some examples of alternative conceptions [https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/], or misconceptions, that some students have expressed. I will then briefly consider the nature of student conceptions in relation to what we might think of as ***scientific*** conceptions. Then I will, again briefly, consider how learners acquire conceptions inconsistent with the canonical scientific accounts.

I will then say a little bit about some common student conceptions of ionic bonding, and how these seem to have a coherence that makes them quite systematic. I will then zoom out a little to talk about a common explanatory principle that students often use in thinking about chemical bonding more broadly, as well as about related themes such as *why reactions occur*, ionisation, and chemical stability.

Finally, I will raise the question of what knowing about learners' thinking might suggest for teaching the chemistry.

Some alternative conceptions

- in NaCl each ion is bonded to one other ion
- a hydrogen bond is a covalent bond from a hydrogen atom to another atom
- in homolytic bond fission, each atom gets it own electron back
- a sodium atom will spontaneously emit an electron
- hydrogen reacts with fluorine to allow the atoms to fill their electron shells
- metals have ionic/covalent/no chemical bonds
- polar bonds are (a subclass of) covalent bonds

So, here are some examples of things students have told me.

These suggestions arose when I was talking to students I taught chemistry at what is called Advanced level in the English school system. Students at this level are usually 16-18 years of age, having done well in their secondary school examinations at age 16, and having selected chemistry as one of 3 or 4 subjects in which to specialise.

I would consider each of these ideas to be an alternative conception [https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/], in that it does not mach the canonical scientific account in some sense.

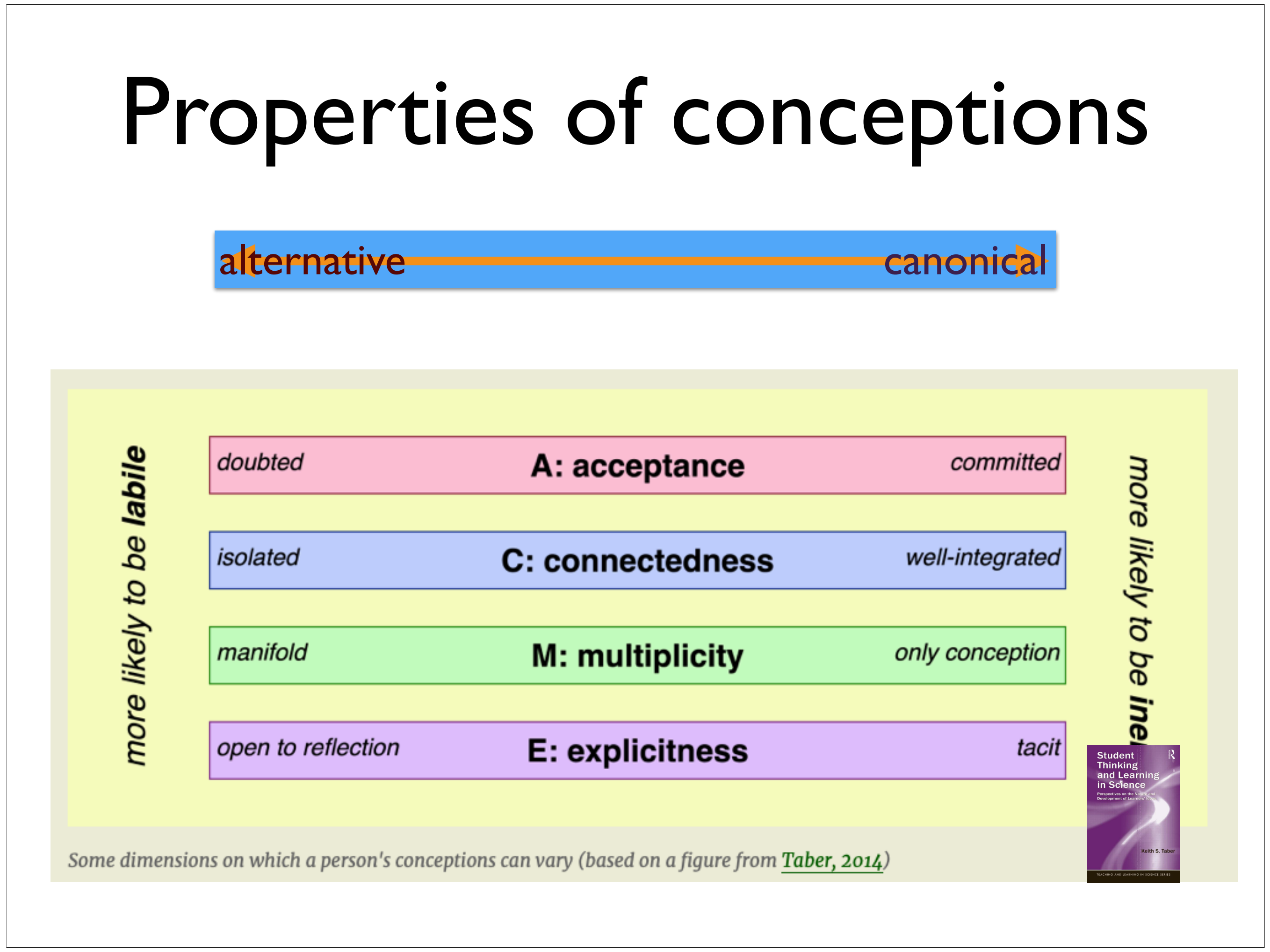
Properties of conceptions

Of course, that is a simplistic label. A conception can be *more or less* at odds with the scientific account.

Sometimes students' ideas are oversimplifications rather than being completely wrong, or they would actually apply in some circumstances but not in a full range of relevant contexts.

Some student ideas are completely contrary to scientific accounts, and others are simply different.

But this is not the only important way that conceptions can vary.



So, for example, just because a student offers a statement which seems inconsistent with the science, that does not mean they are reporting a strongly committed idea. Sometimes that *will* be so, but sometimes they are just making a guess, or expressing a transient intuition, or reporting something that they had heard from a source they do not think is especially reliable.

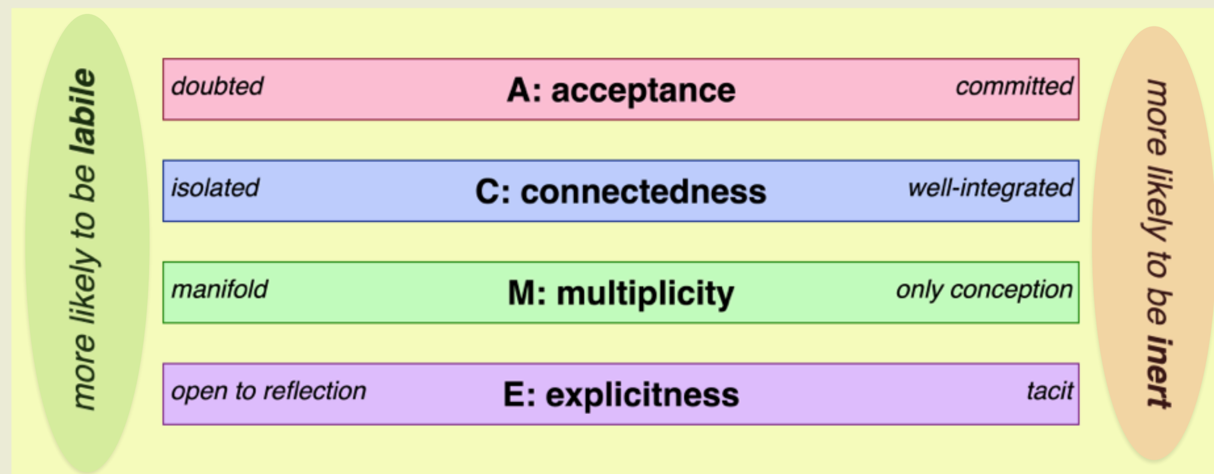
Also, some expressed conceptions are isolated notions that are, in effect, small islands in an ocean of ideas, whereas other ideas are strongly connected into wider webs of meaning, more like cities well connected by the rail networks linking a continent together.

We also cannot assume that just because a learner has one idea, that it represents their ***only*** way of thinking about a topic. Indeed, as an example of that, my own work suggested that often advanced level students had two ways of thinking about ionic bonding, and they would offer an inconsistent set of responses as if they were in transition between a framework they had previously learnt, and what they were being taught on the course.

Finally, sometimes learners have strong intuitions that influence the ideas they express, even though the intuitions themselves remain largely tacit - implicit - so not directly expressed. There is a lot of work on such intuitions in physics education - but it also seems to apply in chemistry learning.

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

Properties of conceptions



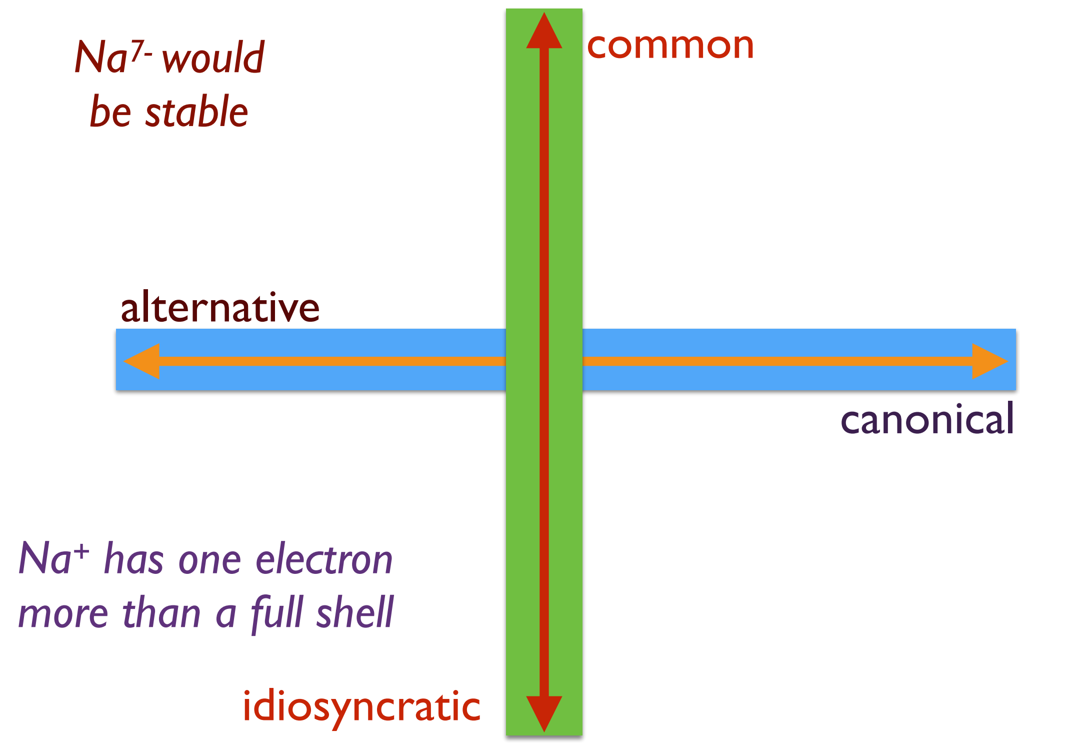
Some dimensions on which a person's conceptions can vary (based on a figure from [*Taber, 2014*]*)*

https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/

The key point here is that ***sometimes*** students' alternative conceptions are not especially significant and will readily be put aside:
but ***sometimes*** they are tenacious and held on to despite extensive efforts to shift student thinking.
In these cases, apparent teacher success in getting students to change their minds sometimes turns out to be a temporary victory.

[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/]

Properties of conceptions

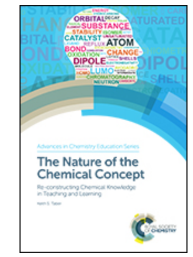


It is also worth pointing out that - although there are some very common alternative conceptions - it is also found that individuals usually have a few personal ideas that are not widely shared.

[https://science-education-research.com/k-plus-represents-a-potassium-atom-that-has-an-extra-electron/]

Concepts

- Concepts act as categories
- Concepts are abstractions from experience
- Concepts are mental entities
- Concepts are tools used in thinking
- Concepts are only apparent when activated
- Concepts act as nodes in a conceptual network



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

https://science-education-research.com/publications/books/the-nature-of-the-chemical-concept/

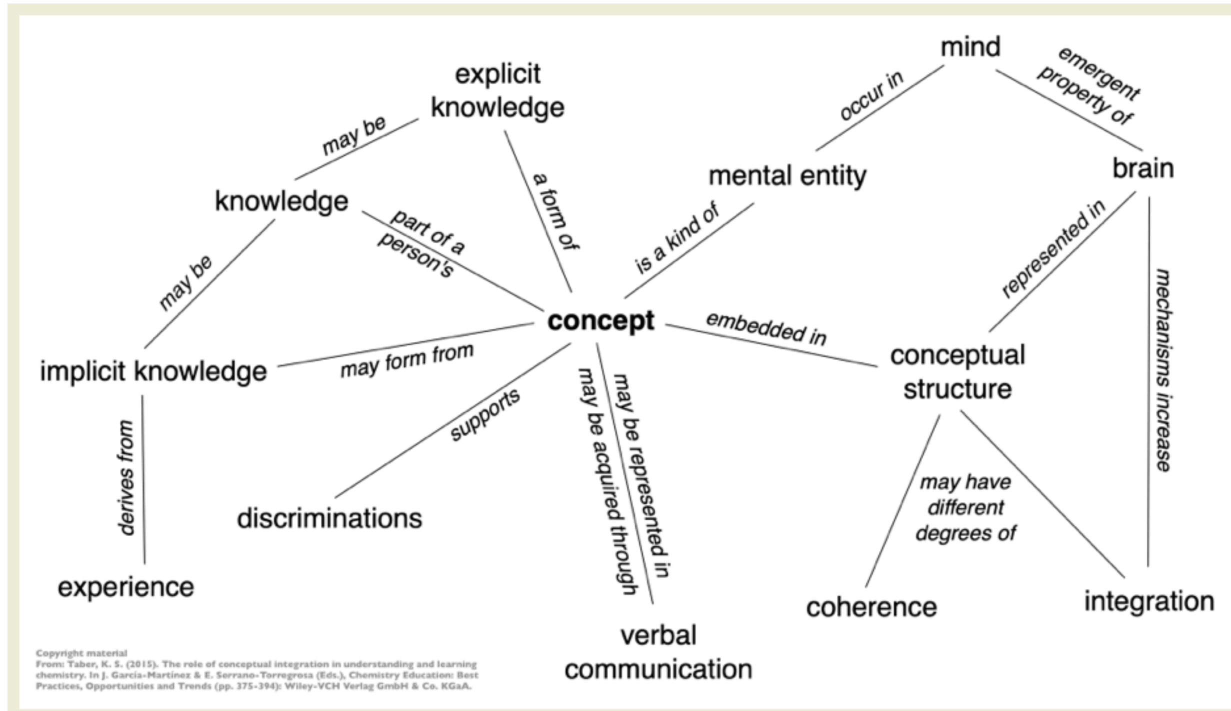
'Concept***ion***' is being used as some aspect of a concept

It is worth taking a moment to be clear about what I mean by the term conception, and perhaps it helps to explain how I use the related word concept. The concept of concept is pretty abstract, as no one can show you a concept, so this is my own take. I do not have time to go into detail, but it is worth making a few points.

- Concepts, as I understand them, only exist 'in' people's minds. Certainly they are represented, in - for example - textbooks, but the concept itself is something ***mental***.
- They do derive from our experiences - but I should be clear this need not always be ***direct*** experience; it could be hearing an account from someone else - or even from imagining a scenario in one's head. (There is a strong argument that all our concepts derive *ultimately* from our experiences in the physical and material environment - yet that may be a very indirect process as suggested by the ideas of Piaget and Vygotsky. The point is, one does not need to have direct experience of a nuclear explosion or a d-orbital to be able to develop a concept.)
- I **do** think that concepts act ***as categories*** in the sense that if someone has some concept of **test-tube** then that person can, in at least some circumstances, make a discrimination about ***whether something is a test tube or not***. If one has some concept of **nucleophile** or **oxidising agent** or *whatever*, then one can, in at least some circumstances, make a discrimination about whether or not something is a **nucleophile**, or **oxidising agent**, or *whatever*. The discrimination may be judged wrong - but one can make a discrimination.
- Finally, concepts can be understood as nodes in a network, such that we can represent this as a concept map - each link on such a map would be a specific conception.

[https://science-education-research.com/publications/books/the-nature-of-the-chemical-concept/]

Concepts act as nodes in a conceptual network

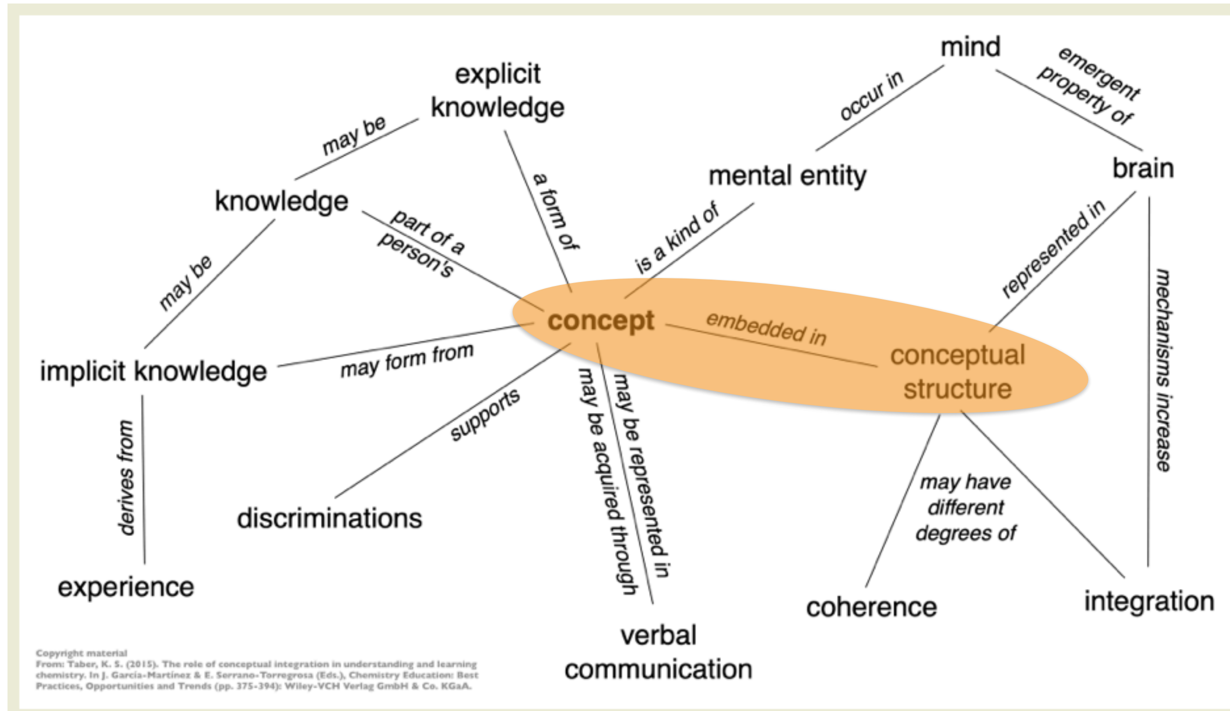


https://science-education-research.com/teaching-science/constructivist-pedagogy/concept-mapping/

So, here is a simple concept map expressing some aspects of someone's concept of…concept.

[https://science-education-research.com/teaching-science/constructivist-pedagogy/concept-mapping/]

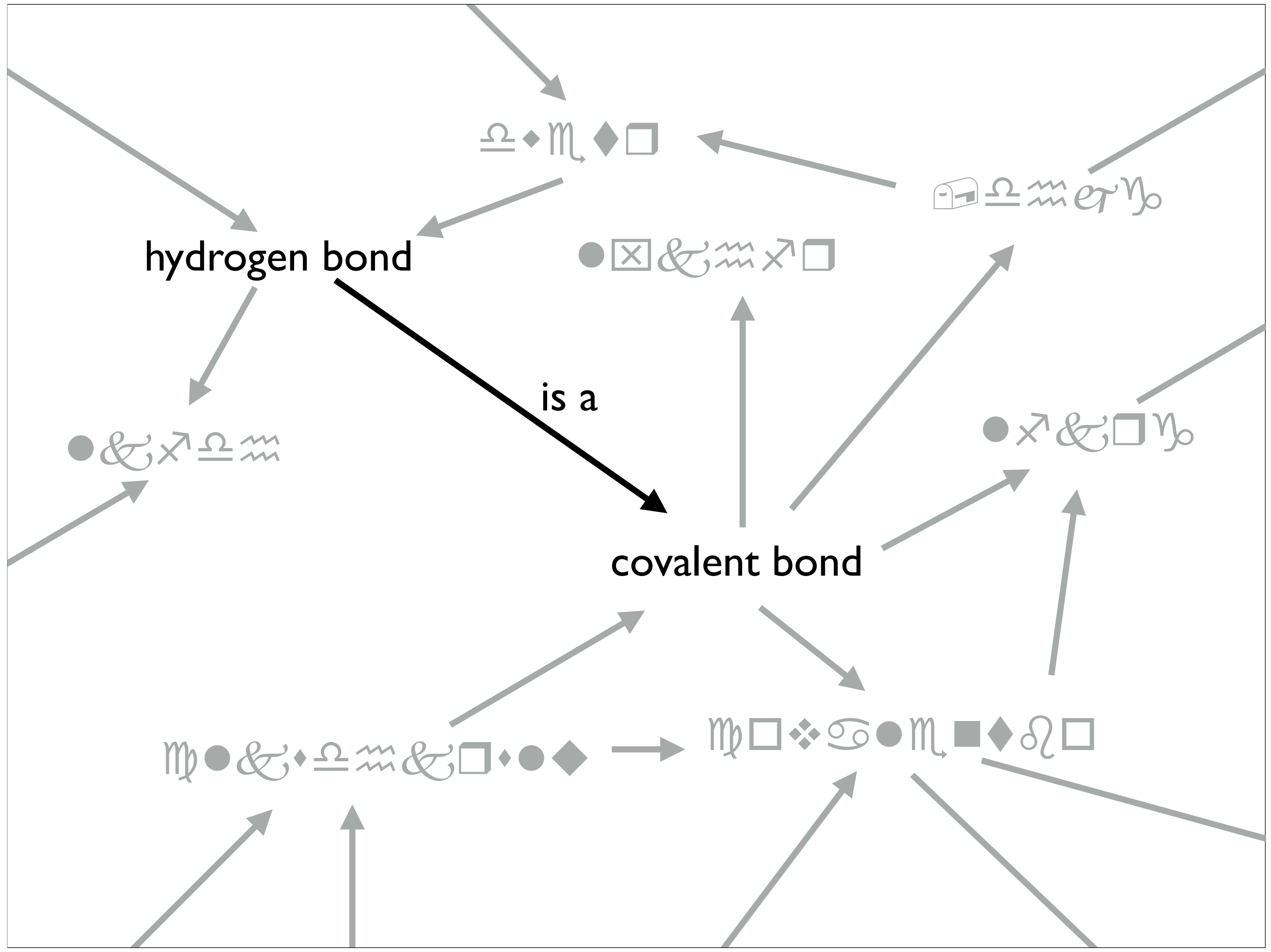
Conception as some aspect of a concept



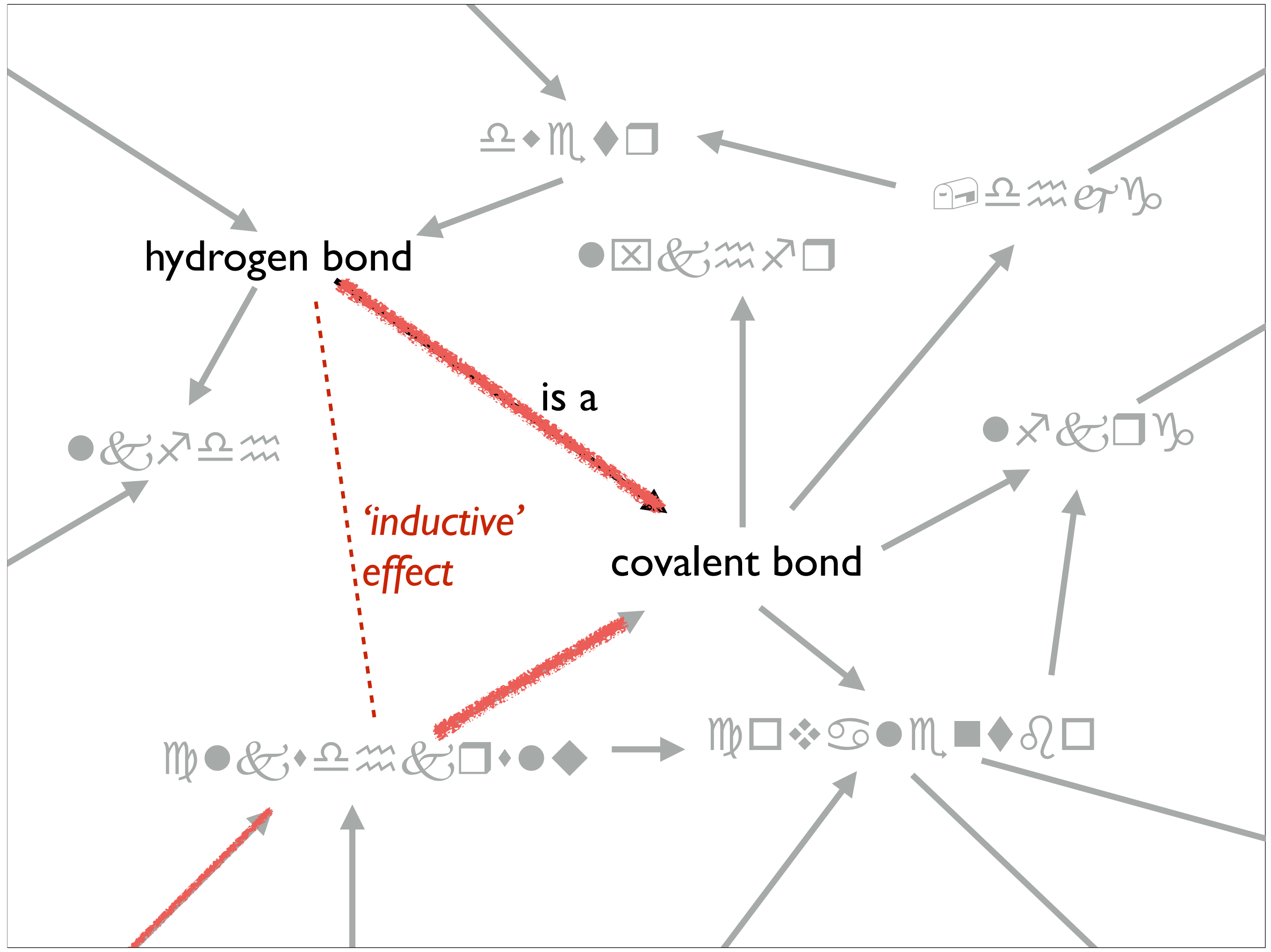
In this model a conception is simply one aspect of a concept.

Put another way, the content of a person's concept is the sum of all their conceptions for that concept.

A diagram such as this simplifies something that is somewhat dynamic and has much more nuance, but is a useful first approximation.



So, for a student with the conception that a hydrogen bond is a covalent bond, this is part of their concept of hydrogen bond, and also one part of their concept of covalent bond.



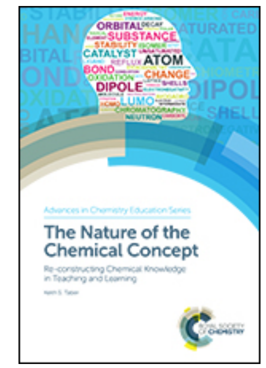
One simplification is that ***as*** concepts are connected to other concepts, which are in turn connected to other concepts, there can be a kind of 'conceptual inductive effect' [https://science-education-research.com/publications/chapters/the-role-of-conceptual-integration-in-understanding-and-learning-chemistry/] in that part of the understanding of a concept is given by its link to another concept but how *that* concept is understood also depends on its various connections

Canonical concepts?

“A canonical concept is taken as **the standard conceptualisation within a field**. Canonical chemical concepts may be considered to have the **authority of being the established ways of making sense** of the discipline of chemistry.”

“…**cannot be found in texts**, as concepts are mental entities accessed by individual people, and texts only contain representations of personal concepts that need to be interpreted to be understood;

…**are not to be found in the shared knowledge of the scientific community**, as the community is highly fragmented, such that there is usually strong conceptual alignment within specific current research programme communities, but much weaker mechanisms to align concepts across the wider discipline and beyond…”



If concepts are only actually found in minds, as I suggest, then what about the concepts of chemistry itself. That is the concepts that teachers teach and that students are meant to learn and be assessed against. It turns out to be rather hard to actually **locate** any *actual* canonical concepts.

Texts just contain representations, such as sentences which need to be interpreted (through the reader’s repertoire of existing ideas).

And it is surely naïve to suggest that any chemical concepts such as, say, metallic bond, or transition metal, or aromaticity, or acid, are *entirely* shared by all chemists, or all chemistry teachers. That is, we would not expect to draw *identical* concepts maps if representing the conceptual knowledge of different chemists.
So, as teachers, we need ***the idea of*** canonical concepts - but I am not sure that there actually really are any.

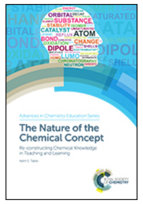
[https://science-education-research.com/publications/books/the-nature-of-the-chemical-concept/]

Canonical concepts?

The canonical concept is a useful fiction

The curriculum comprises of *representations of* scientific knowledge - simplifications, curricular models

"there are three relevant distinctions here:
(i) everyday concepts and scientific concepts;
(ii) historical (scientific) concepts and current (scientific) concepts;
(iii) canonical (current scientific) concepts and mooted (current scientific) concepts."



Many **historical** scientific conceptions (phlogiston, caloric, inert gases, etc.) would not be considered ***canonical*** now - but ***alternative*** conceptions.

So, I am not sure it is entirely helpful to think of the official concepts of chemistry on the one hand, juxtaposed against student's conceptions on the other. Even professional chemists, and if I may suggest, chemistry teachers, are likely to have some idiosyncratic 'alternative conceptions' in the subject.

Rather, there are just people who have chemical concepts that comprise of sets of conceptions that are shared to varying degrees.
After all, Joseph Priestley is a famous chemist who expained combustion in terms of phlogiston [https://science-education-research.com/learners-concepts-and-thinking/historical-scientific-conceptions/] - but if a student came up with such an idea today it would be an alternative conception.

I am not suggesting that we do not need to address students' alternative conceptions, but just that we should not see an absolute distinction between chemical concepts and misconceptions.

[https://science-education-research.com/publications/books/the-nature-of-the-chemical-concept/]

Sources of conceptions?

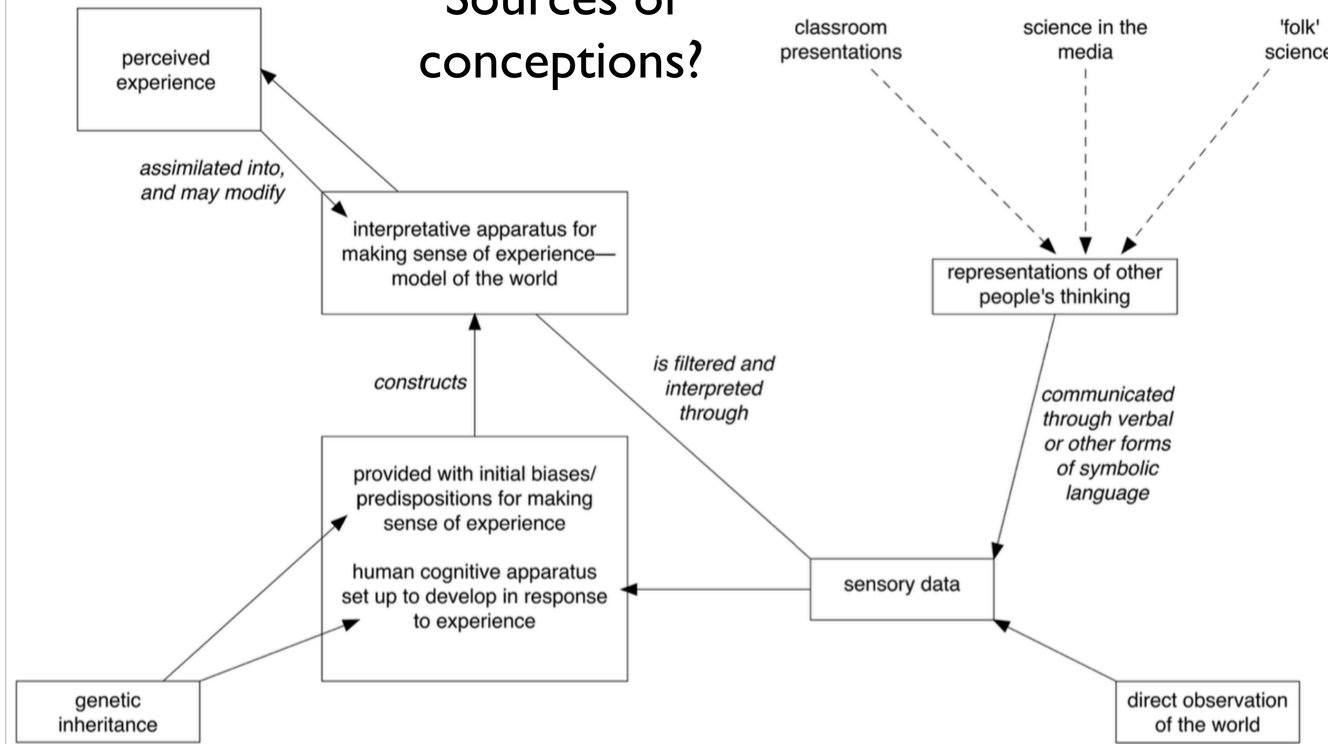


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

https://science-education-research.com/publications/books/student-thinking-and-learning-in-science/

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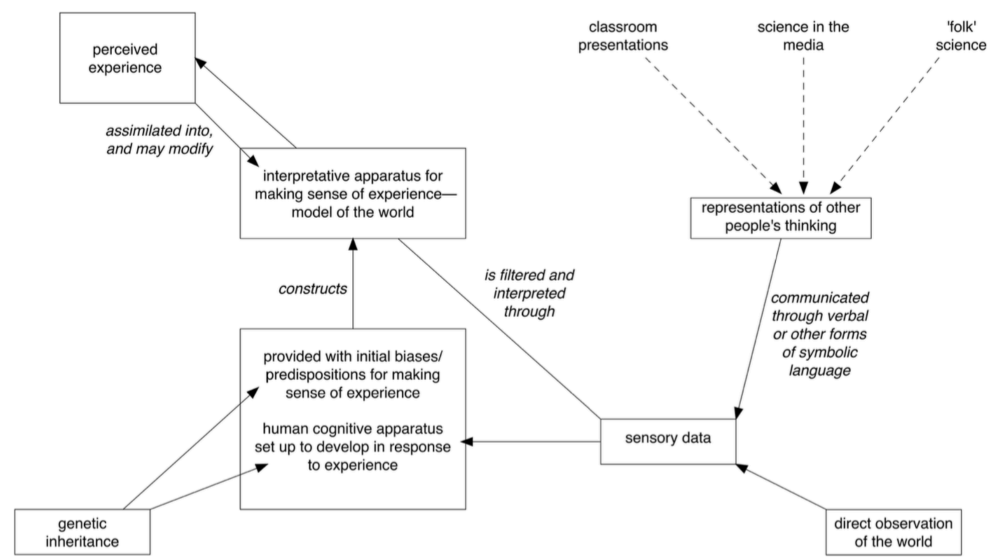
Sources of conceptions



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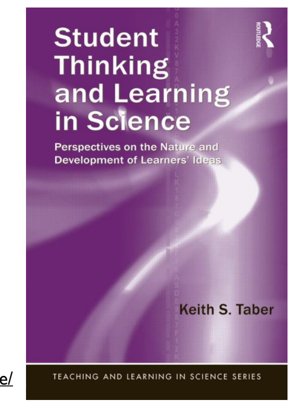


https://science-education-research.com/publications/books/student-thinking-and-learning-in-science/

Where do conceptions come from?

I have suggested* they are abstractions from experience.

* I am NOT, of course, suggesting this is my original idea!

Sources of conceptions

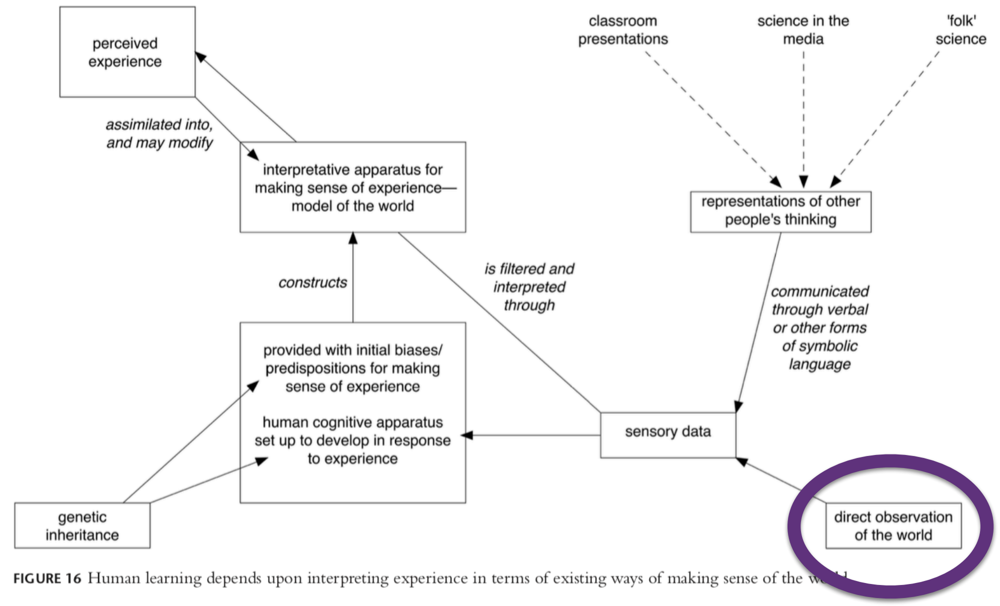


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the w

motion is inherently transient

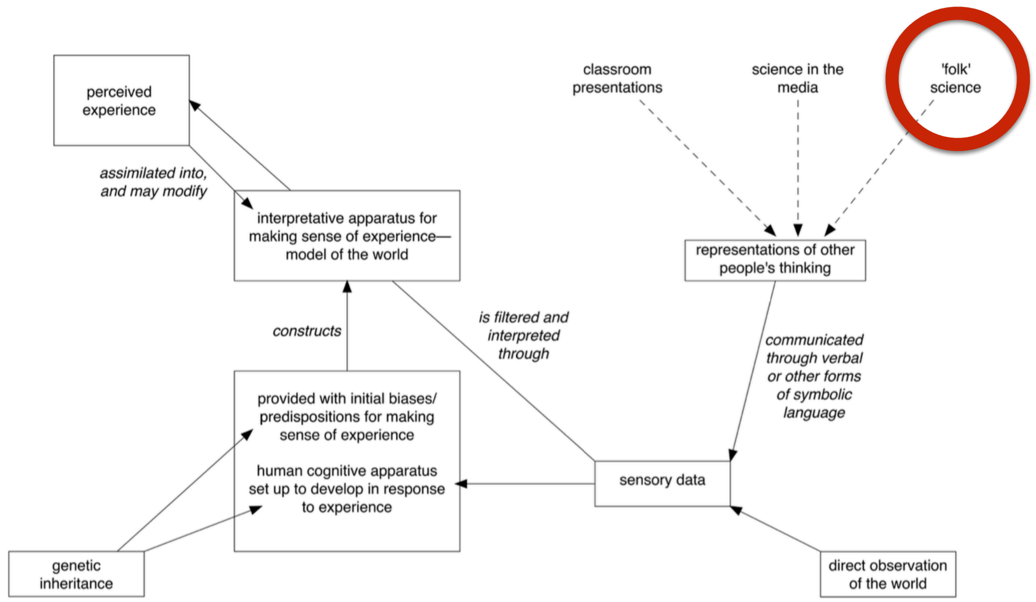
Sometimes this means direct experience of the world.

Some of the common alternative conceptions found in physics and biology would certainly seem to be derived, at least to some extent, from early life experience.

We can understand why Newton's first law [https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/newtons-first-law/] is difficult to accept when all of our experience tells us that moving objects soon stop moving once there is no force driving them along.

This is less persuasive in considering student ideas about molecules, and bonds, and the like.

Sources of conceptions



All 'chemicals' are dangerous and unnatural

FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

But we can appreciate that some common chemical ideas are met in everyday social discourse.

95% natural origin

95% natural origin

73% purified water and 22% natural derived ingredients other 5% for a good usage experience & product stability.

The *Herbal Essences* **Coconut Milk conditioner** is, according to their website,

> *95% natural origin*
> *73% purified water and 22% natural derived ingredients other 5% for a good usage experience & product stability.*
>
> — https://herbalessences.co.uk/en-gb/products/coconut-milk/coconut-milk-shampoo/

5% magical ingredients?

Of mostly natural origin

Keith

2021-09-01

science in the media, tautology, technical language

fluoride in drinking water, natural products

Is your shampoo of natural, unnatural, or supernatural origin?

Keith S. Taber

https://science-education-research.com/of-mostly-natural-origin/

[https://science-education-research.com/of-mostly-natural-origin/]

Sources of conceptions

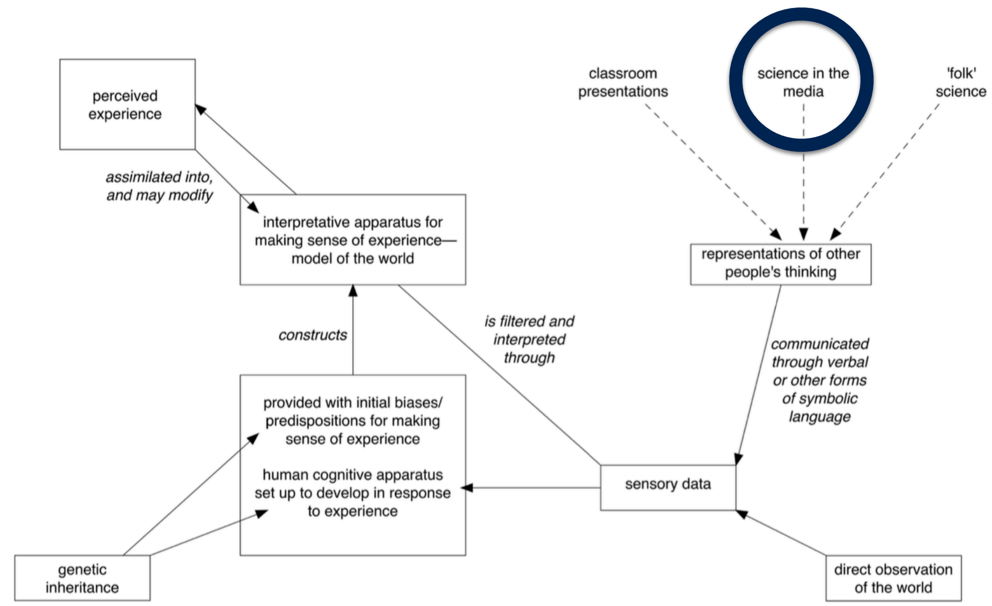


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

"This could only mean one thing…"

There is also the way science is presented in the media. I recall noticing how many television science documentaries would present some piece of evidence or argument and then conclude 'this could only mean one thing' [https://science-education-research.com/this-can-only-meanits-the-core-of-a-giant-planet/] which is perhaps one of the least scientific phrases in the language.

Sources of conceptions

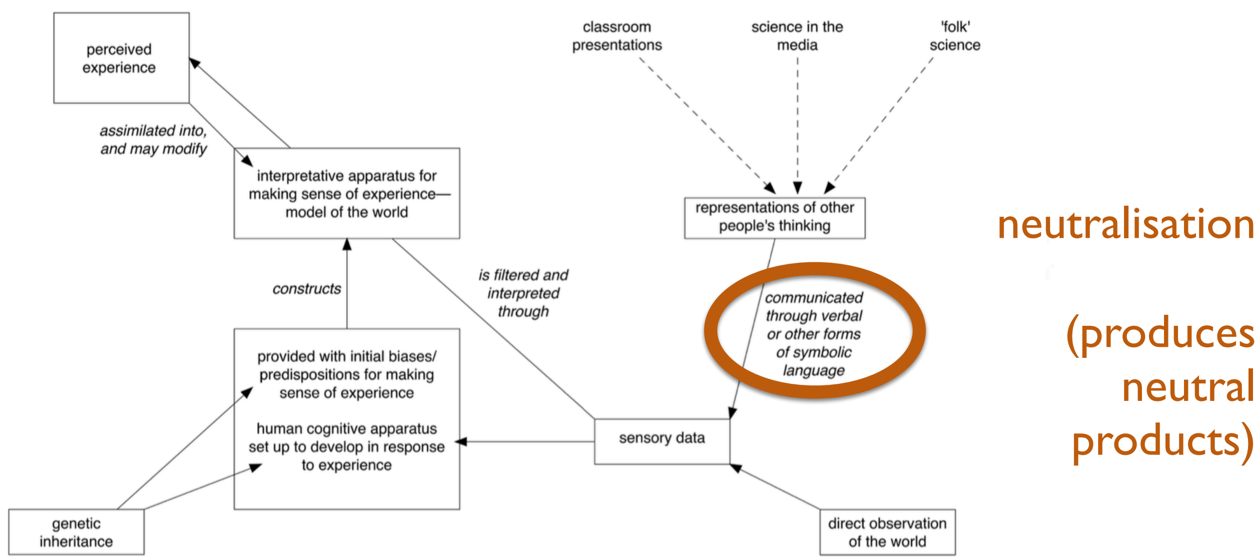


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

Then, there is the way language is understood, which is not always how it is intended.

A classic example is the English term neutralisation, which implies for many students *a process that produces something neutral.*

There should be no surprise that they often assume that *the neutralisation of **any** acid with **any** base gives a neutral product.*

It does not help that often the only examples met in introductory courses fit with the alternative conception, so it is well entrenched by the time the students meet counter-examples.

Sources of conceptions

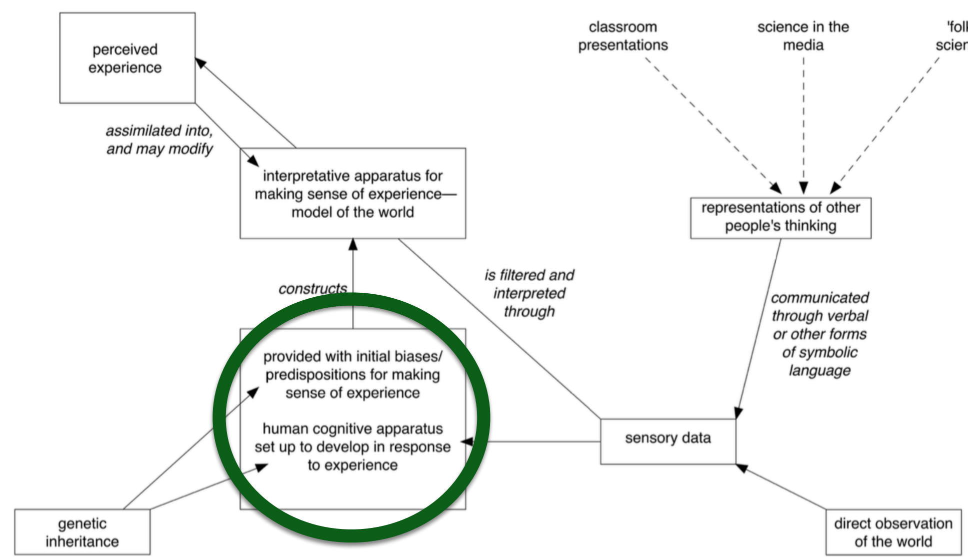


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

full shells are better

There are also intuitions we have about the nature of the world, some of which may even have been inherited because they have proved largely helpful in the past.

The intuition that ***something that is complete and symmetrical and full has special properties*** is surely influencing student thinking about full electron shells.

The intuition that the atomic nucleus provides a certain amount of force to be ***shared-out*** among the electrons seems very common - but sadly does not match the scientific account.

[https://science-education-research.com/publications/papers/learning-processes-in-chemistry/]

Sources of conceptions

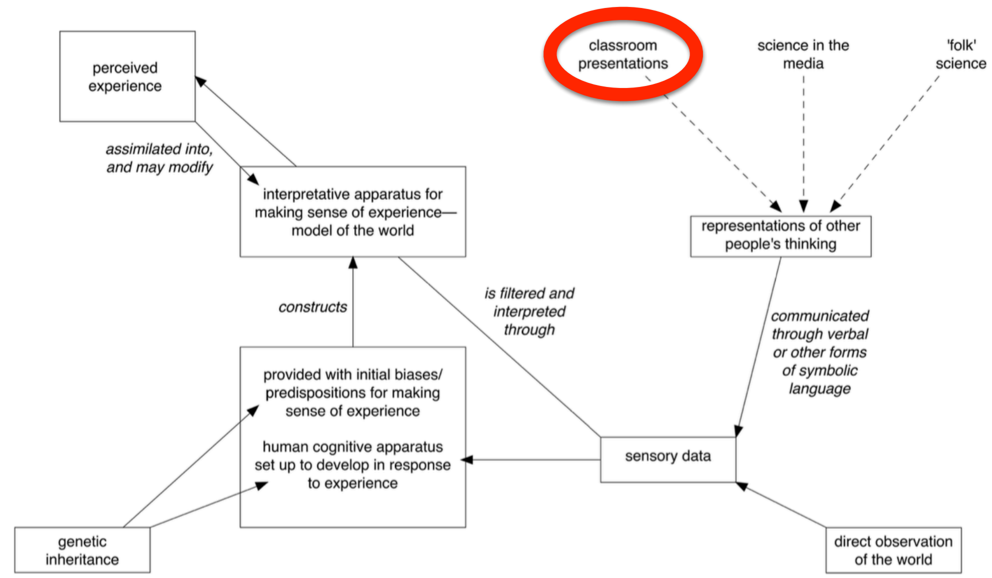


FIGURE 16 Human learning depends upon interpreting experience in terms of existing ways of making sense of the world.

the ionic bond is due to electron transfer?

?

But, given that many alternative chemical conceptions are about entities that students have never directly experienced…

…atoms, molecules, ions, electrons, bonds…

it seems likely that ***the way we teach some topics*** also contributes to students' alternative conceptions

Molecular framework for ionic bonding

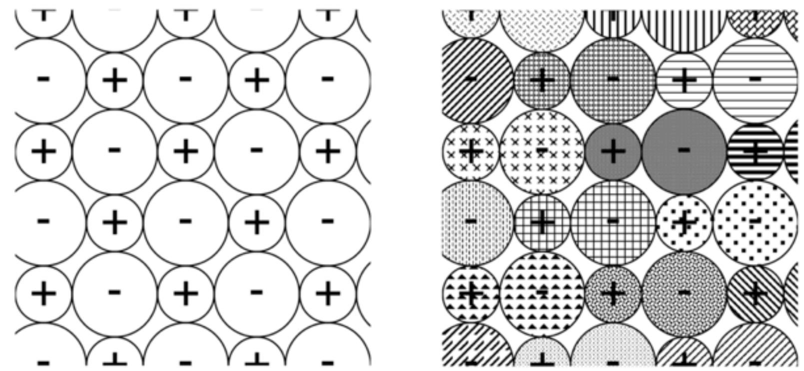


Figure 3: When shown an image of an ionic lattice (left hand image), some students will happily nominate pairs of ions as being bonded together, but only attracted to other equally close counter ions by weaker forces – conceptualising the structure as containing discrete molecule-like entities (right-hand image).

From Taber, 2013

https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/

One concept that often seems to be misunderstood by students is ionic bonding.

It is common for learners to assume there are molecules, or at least molecule-like ion-pairs that have a somewhat independent nature, within a solid such as sodium chloride.

[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/]

[https://science-education-research.com/publications/articles/student-understanding-of-ionic-bonding/]

Molecular framework for ionic bonding

alternative conceptual framework

canonical

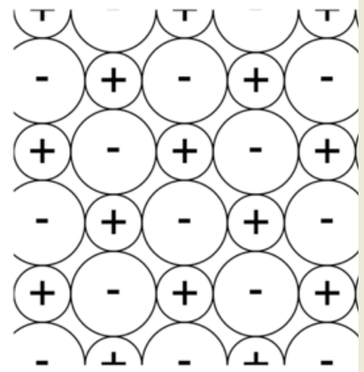


Figure 3: When shown an image
students will happily nominate
only attracted to other equall
conceptualising the structure as
(righ

From Taber, 2013

	MOLECULAR FRAMEWORK	ELECTROSTATIC FRAMEWORK
status	alternative framework	curricular science
role of molecules	ion-pairs are implied to act as molecules of an ionic substance	ionic structures do not contain molecules - there are no discrete ion-pairs in the lattice
focus	the electron transfer event through which ions may be formed	the force between adjacent oppositely charged ions in the lattice
valency conjecture	atomic electronic configuration determines the number of ionic bonds formed. (e.g.: a sodium atom can only donate one electron, so it can only form an ionic bond to one chlorine atom.)	the number of bonds formed depends on the coordination number, not the valency or ionic charge (e.g.: the coordination is 6:6 in NaCl)
history conjecture	bonds are only formed between atoms that donate / accept electrons. (e.g.: in sodium chloride a chloride ion is bonded to the specific sodium ion that donated an electron to that particular anion, and *vice versa*.)	electrostatic forces depend on charge magnitudes and separations, not prior configurations of the system (e.g.: in sodium chloride a chloride ion is bonded to six neighbouring sodium ions)
'just forces' conjecture	ions interact with the counter ions around them, but for those not ionically bonded these interactions are just forces. (e.g.: in sodium chloride, a chloride ion is bonded to one sodium ion, and attracted to a further five sodium ions, but just by forces - not bonds.)	a chemical bond is just the result of electrostatic forces - ionic bonds are nothing more than this (e.g. the forces between a chloride ion and each of the neighbouring sodium ions are equal.)

From: Taber, K. S. (1997) Student understanding of ionic bonding: molecular versus electrostatic thinking?, School Science Review, 78

https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/

Often students suggest that a sodium ion or a chloride ion can only form an ionic bond with **one** other ion, and that indeed an ionic bond **only** exists where a sodium atom has donated an electron to a chlorine atom.

Students will happily tell this fairy story even if they have themselves prepared sodium chloride from solutions of sodium hydroxide and hydrochloric acid. This seems bizarre, but is common.

The integrity of the solid lattice will be explained in terms of the charges on the ions that mean that each ion is attracted to those oppositely charged neighbours around it, including those that it is not bonded to.

That is, in this *symmetrical* lattice an ion is [considered to be] ionically bonded to ***one other*** ion, but also attracted to others just by force. The ionic bond itself is not considered a force, not an electrostatic attraction; but the result of some transactional history between two hypothetical neutral atoms.

[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/]

[https://science-education-research.com/publications/articles/student-understanding-of-ionic-bonding/]

Molecular framework for ionic bonding

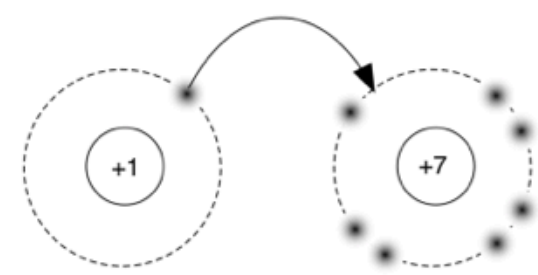


Figure 2: Students commonly identify a chemically unlikely electron transfer between isolated atoms as being the ionic bond

https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/

Students will often represent ionic bonds in terms of such an unlikely process as this.

Where do they think these neutral atoms are to be found?

The process shown here is of course energetically non-viable.

But to be fair, I have seen diagrams such as this in many text books, and even in exam papers. Perhaps some of you use such figures, even though they do not represent any viable chemistry?

[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-molecular-framework-for-ionic-bonding/]

Molecular framework for ionic bonding

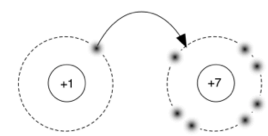


Figure 2: Students commonly identify a chemically unlikely electron transfer between isolated atoms as being the ionic bond

covalent bonding

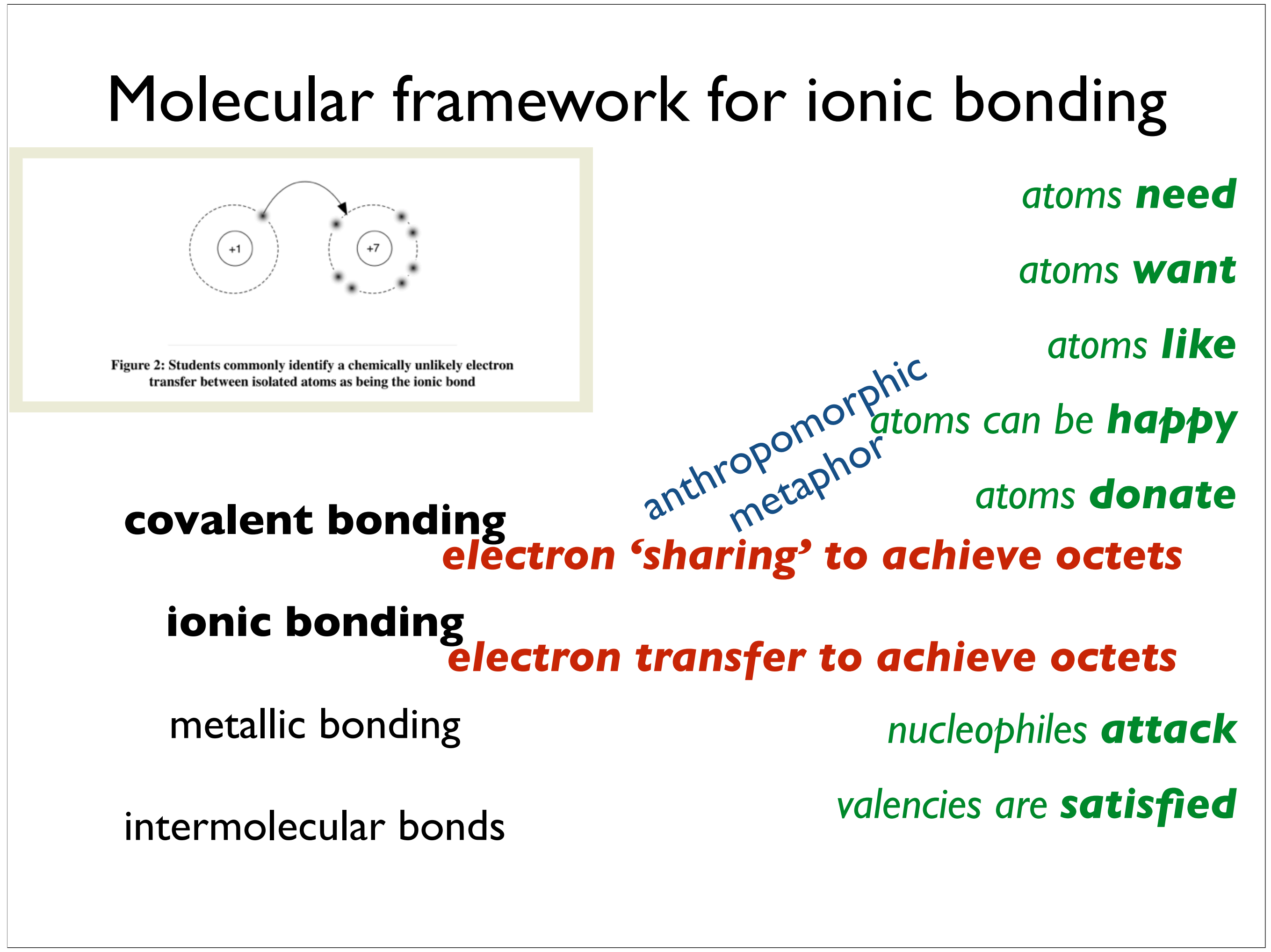
ionic bonding

metallic bonding

intermolecular bonds

In what order ***do you*** introduce different forms of chemical bonding?

I think it is very common to introduce covalent first, then ionic - in which case students will be making sense of ionic bonding in terms of their prior learning about bonding in discrete molecules.



Sometimes only these two forms of bonding are introduced, perhaps explained in terms of electron sharing (whatever ***that*** actually means) and electron transfer - as the two methods that allow atoms to obtain full shells.

Students do not always realise that these kinds of expressions are meant metaphorically.

[https://science-education-research.com/learners-concepts-and-thinking/anthropomorphism/]

[https://science-education-research.com/publications/papers/the-secret-life-of-the-chemical-bond/]

Molecular framework for ionic bonding

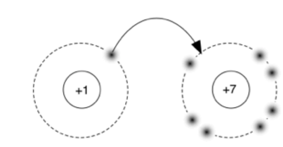
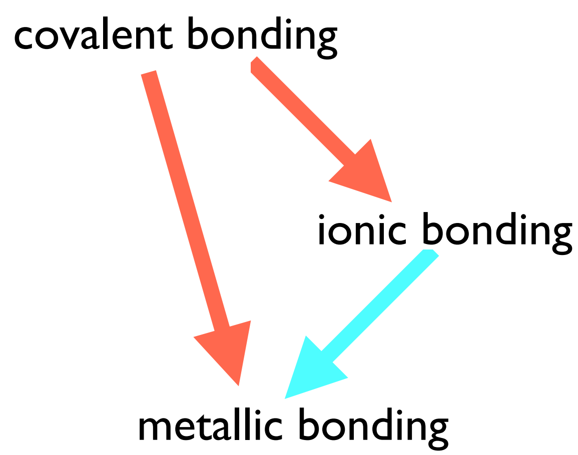
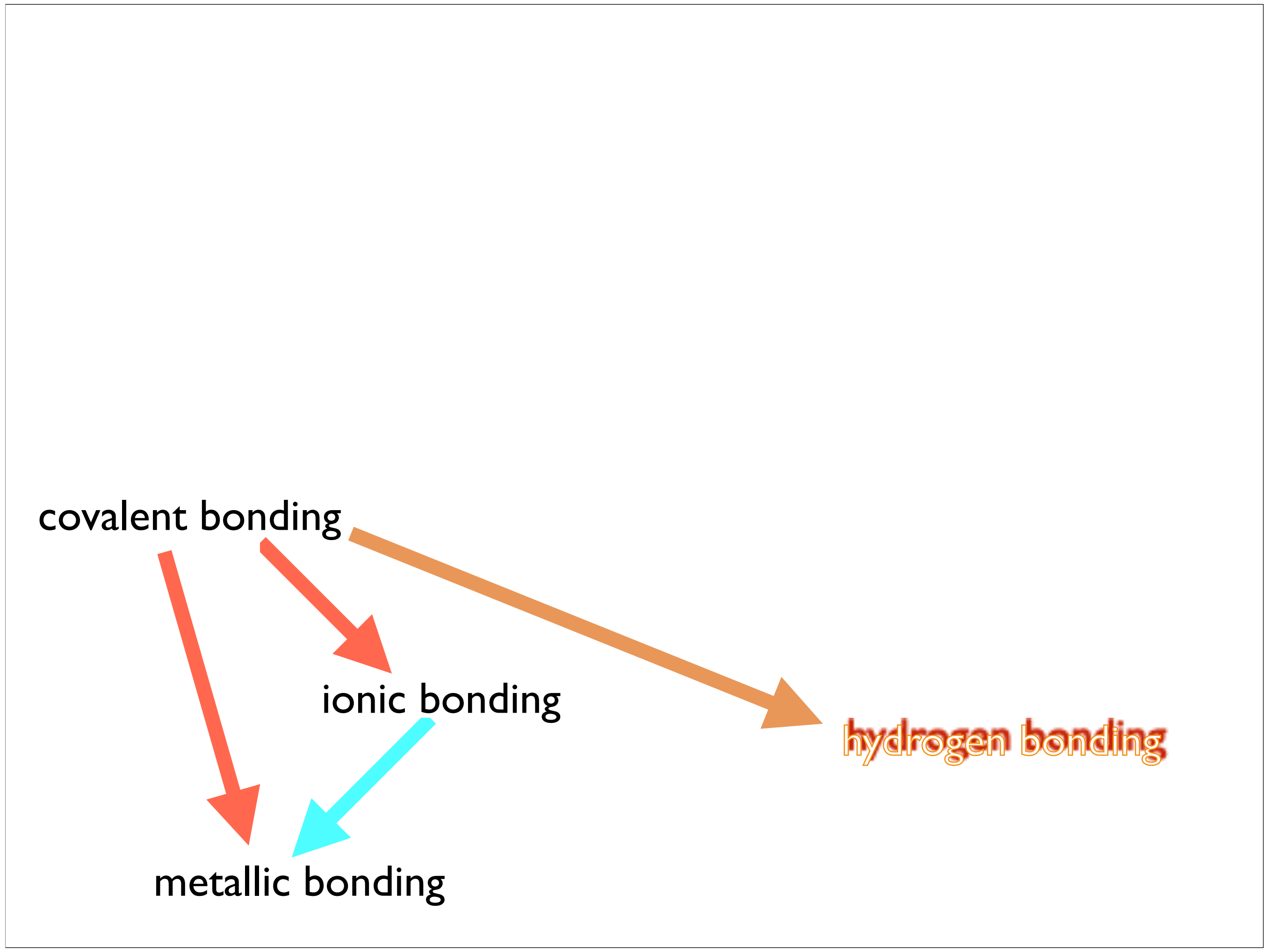


Figure 2: Students commonly identify a chemically unlikely electron transfer between isolated atoms as being the ionic bond



This may explain why metallic bonding is variously understood as a form of covalent bonding; a form of ionic bonding; a combination of ionic and covalent bonding; or having no bonding at all.

[https://science-education-research.com/publications/papers/mediating-mental-models-of-metals/]



Where students meet hydrogen bonds in biology, but have not yet been taught about them in chemistry, they may readily assume they are just *covalent bonds to hydrogen* - as their only basis for making sense of hydrogen bonds is the dichotomy of ionic or covalent bonds

Sequencing?

A teaching order that
builds up complexity:

metallic bonding

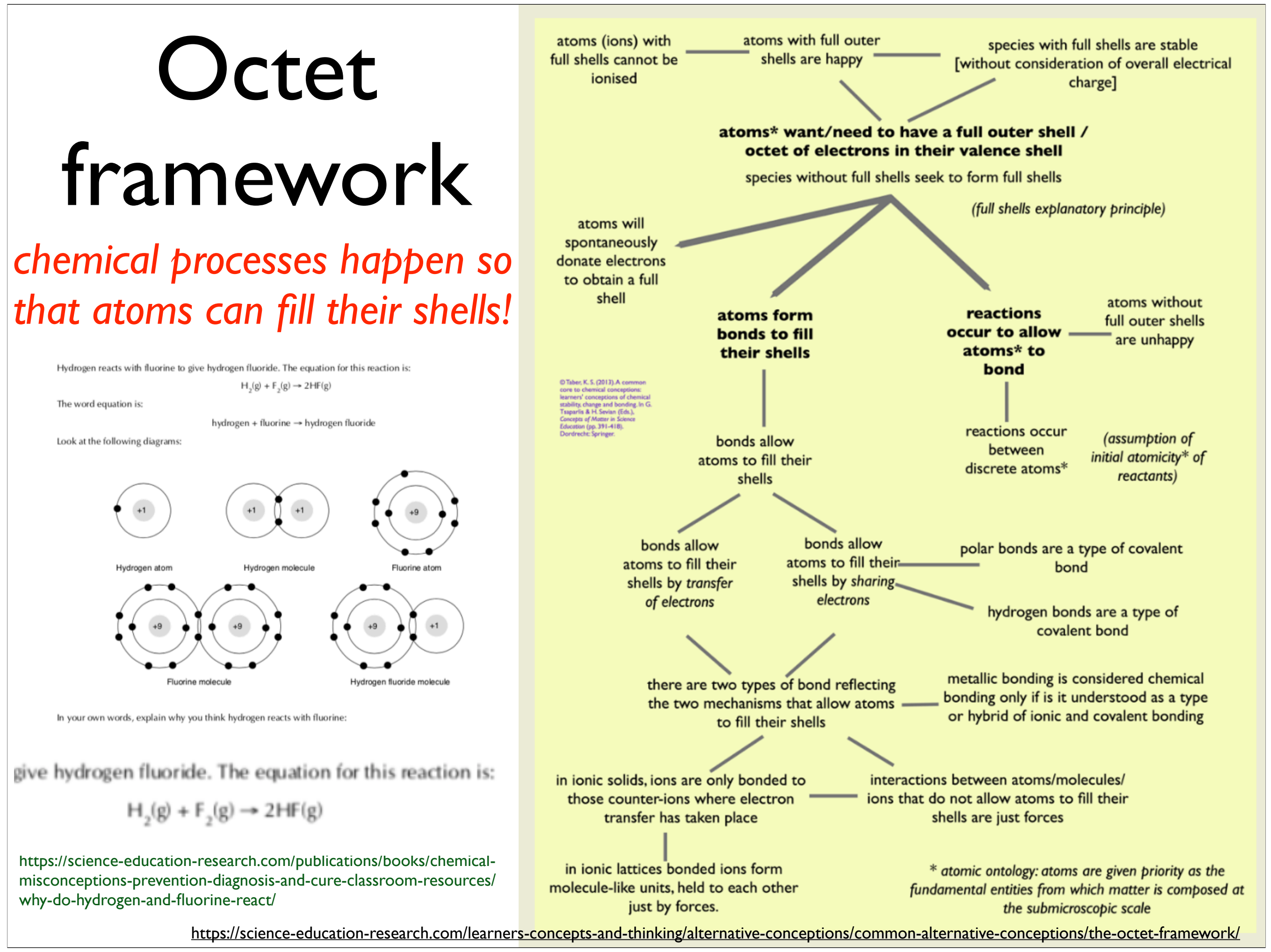
ionic bonding

covalent bonding (giant structures)

covalent + intermolecular bonding (molecular)

Perhaps there is a more sensible teaching order?

[https://science-education-research.com/publications/papers/building-the-structural-concepts-of-chemistry/]



The molecular framework for ionic bonding is part of a more extensive framework of ideas which are based around the notion that **chemical processes occur to allow atoms to obtain octets of electrons or to fill their outer shells**.

This requires an ***assumption of initial atomicity*** - that in doing chemistry we start with atoms - which, of course, is very, very seldom the case.

Yet even if we ask students about why reactions occur, and *remind them we are dealing with molecules*, they still often explain that the reaction occurred so that the atoms could fill their shells. The octet rule, an often useful **heuristic** for determining which molecules and ions are likely to be stable, is commonly adopted as an ***explanation*** *for why chemistry occurs* - even when the reactants meet the octet rule just as well as the products.

[https://science-education-research.com/learners-concepts-and-thinking/alternative-conceptions/common-alternative-conceptions/the-octet-framework/]

[https://science-education-research.com/publications/papers/an-alternative-conceptual-framework/]

Spontaneous ionisation

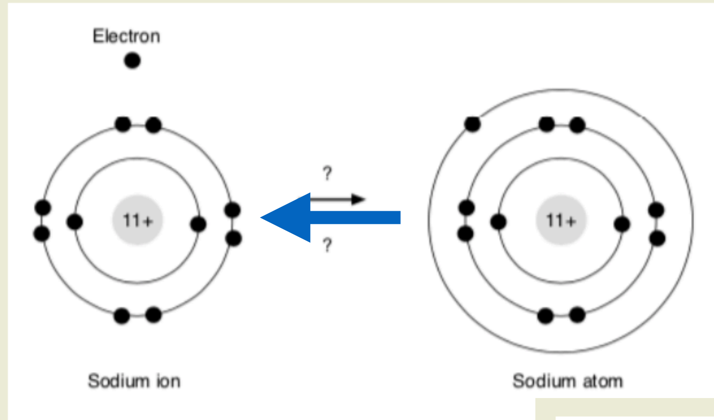


Image presented in the diagnostic instrument 'Stability and reactivity'

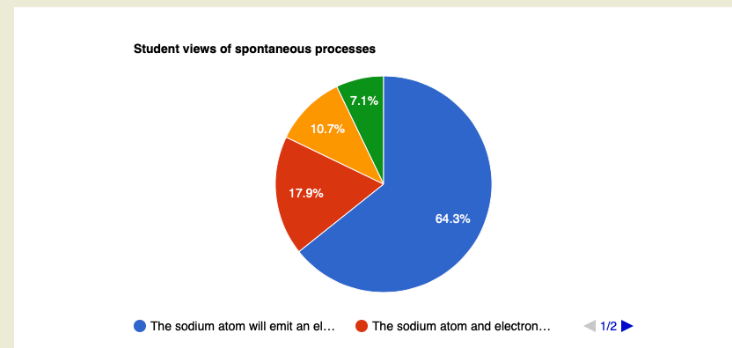


Chart by Visualizer

https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/

Even though we teach students about ionisation energies, they will often assume that atoms will spontaneously emit electrons to achieve full shells or octets.

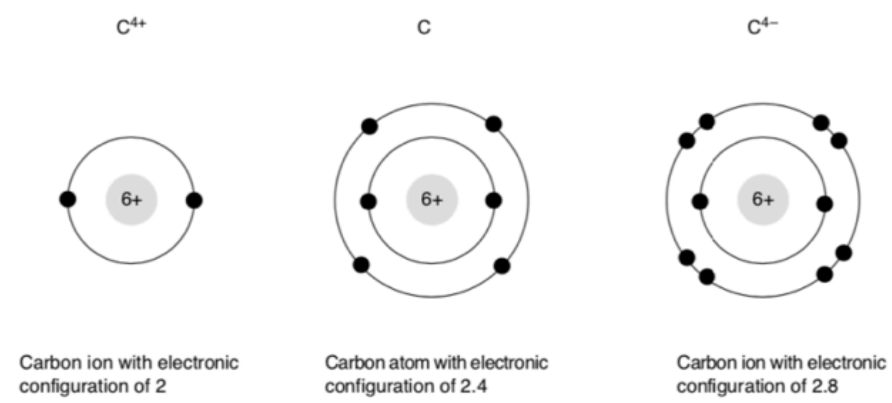
They may also suggest that when an atom is ionised, no further ionisation will be possible once an ion is produced which has a full outer shell or octet.

[https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/]

[https://science-education-research.com/publications/papers/students-conceptions-of-chemical-stability/]

Chemical stability

The diagrams below represent three chemical species:-



*Comparing the stability of different species (From the diagnostic probe '**Chemical Stability**')*

Judgement of relative stability	Selection of judgement	Octet thinking justification
C^{4+} is more stable than C	17/30	16/17
C is less stable than C^{4-}	17/30	15/17

*Student judgements of relative stability – and the level of justifications in terms of **octet thinking** (octets/full outer shells) From Taber, 2009*

https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/

Students will often assume highly charged ions are stable as long as they have full shells.

[https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/]

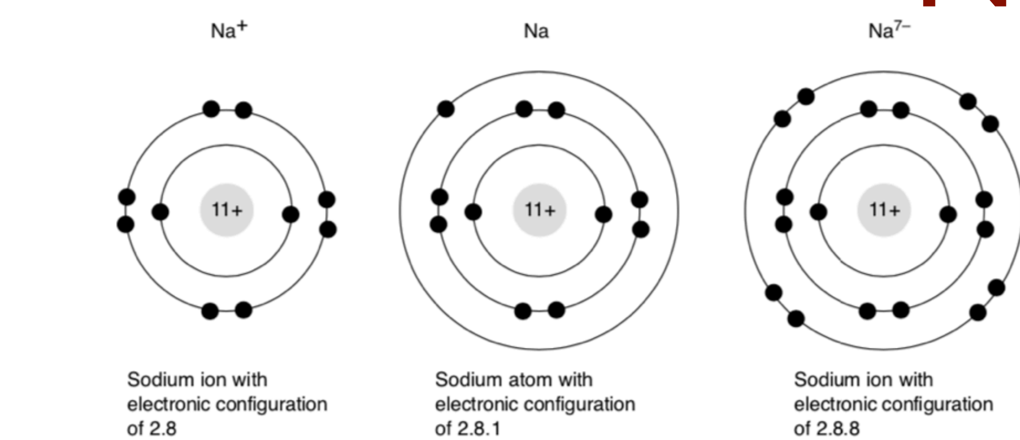
[https://science-education-research.com/publications/papers/students-conceptions-of-chemical-stability/]

Chemical stability

Na^{7-}!

Most students though the Na^{7-} anion was more stable than the atom

The diagrams below represent three chemical species:-



Comparing the stability of different species (From the diagnostic probe '[Chemical Stability](#)')

Judgement of relative stability	Selection of judgement	Octet thinking justification
Na^{+} is more stable than Na	27/33	22/27
Na^{7-} is more stable than Na	21/33	17/21

https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/

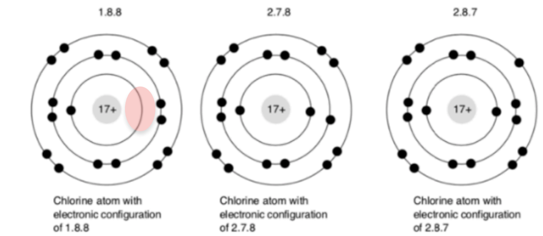
Even a highly charged metal anion.

[https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/]

[https://science-education-research.com/publications/papers/students-conceptions-of-chemical-stability/]

Chemical stability

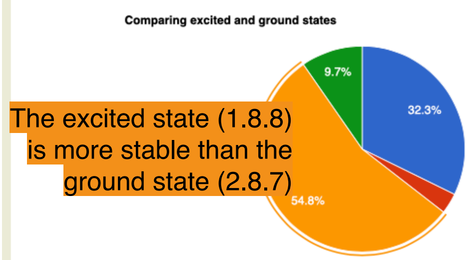
The diagrams below represent three chemical species:-



Comparing the stability of different species (From the diagnostic probe 'Chemical Stability')

Judgement of relative stability	Selection of judgement	Octet thinking justification
[more excited state] Cl (1.8.8) is at least as stable as [less excited state] Cl (2.7.8)	20/31	14/20
[excited state] Cl (2.7.8) is more stable than the [ground state] Cl (2.8.7)	14/31	11/14
[ground state] Cl (2.8.7) is less stable than the [excited state] Cl (1.8.8)	17/31	12/17

Student judgements of relative stability – and the level of justifications in terms of octet thinking (octets/full outer shells). From Taber, 2009



Teachers tend to focus on the outer shell because (chemically) that's usually *where the action is*, but

learners may assume a full outer shell is more important to stability than a full inner shell!

https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/

They may even think that an excited atom is more stable than its ground state if promoting an electron allows the atom to have an outer shell with an octet of electrons.

[https://science-education-research.com/science-concepts/conceptions-of-chemical-stability/]

[https://science-education-research.com/publications/papers/students-conceptions-of-chemical-stability/]

Conclusions

Alternative conceptions of chemical bonding (and associated topics) seem to be very common.

Many of these conceptions seem to link to the full outer shell explanatory principle

(that atoms want/need/act to obtain octets/full outer shells).

Intuitions seem to influence student thinking…

…stability of a full shell;

force from a nucleus being 'shared out';

electrons pushing the nucleus together,…

…but as students have no *direct* experience of atoms and bonds, it seems likely that ***the way the topic is represented and taught has a substantial influence.***

I do not think we should be looking to blame teachers for the intuitions that lead to students misunderstanding chemical ideas and forming alternative conceptions.

Yet it seems very likely that the way topics are taught is influencing those common alternative conceptions that students seem to acquire and find it difficult to move beyond.

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Thank you

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