





Making Thinking Visible in Chemistry

Academy of Singapore Teachers
Teacher Led Workshop

Course Code: CHM - 000063

Friday 21st April 2023
2.30 to 5.00 p.m.

Making Thinking Visible in Chemistry

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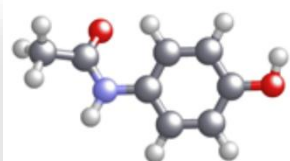
Making Thinking Visible in Chemistry



- A copy of this presentation can be found online at:

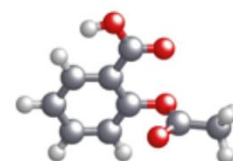
www.Scientist.sg

Making Thinking Visible in Chemistry



Scientist.sg

Online Documents for Chemistry Teachers



- 1) Applied Learning
- 2) Concept Based Teaching
- 3) Critical Thinking
- 4) Designing a Concept Based Curriculum
- 5) Differentiated Classroom
- 6) Educational Games
- 7) Making Thinking Visible in Chemistry
- 8) Qualities of Effective Teachers
- 9) Scientific Literacy
- 10) The Nature and Philosophy of Science

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Making Thinking Visible in Chemistry



• Introductory video: 14 seconds.

- What do you think she is thinking?

Making Thinking Visible in Chemistry



What will be
covered during this
workshop?

Making Thinking Visible in Chemistry

Main Menu (*click to link*)

1. Introduction.
2. Examples of Misconceptions.
3. Harvard Project Zero Thinking Routines.
4. Using M&M's® to Represent Particles.
5. Using Magnets to Represent Particles.
6. Using Magnets to Represent Shapes of Molecules.
7. Pictionary – Drawing and Sketching Ideas.
8. Taboo – Making Ideas Distinct and Clear.
9. Concept Cartoons.

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[Main Menu](#) (*click to link*)

- [10.](#) My Favourite Mistake.
- [11.](#) SEXI – Analogies and Abstract Illustrations.
- [12.](#) Predict – Observe – Explain.
- [13.](#) Co-operative Learning Strategies.
- [14.](#) Curiosity Cubes and Thinking Tubes.
- [15.](#) Habits of Mind.
- [16.](#) Using LEGO® to Represent Particles.
- [17.](#) Using LEGO® to Communicate Ideas.
- [18.](#) Socratic Questioning.

Making Thinking Visible in Chemistry

[Main Menu](#) (*click to link*)

[19.](#) Teachers Model Critical and Creative Thinking.

[20.](#) Authentic Transfer Task (Performance Task).

[21.](#) Students Model – Kinetic Particle Theory.

[22.](#) Students Model – Rate of Reaction.

[23.](#) Animations.

[24.](#) Traffic Lights.

[25.](#) Integration with Technology.

[26.](#) Mind-maps.

[27.](#) In a Nutshell – Summary.

[28.](#) References.

Making Thinking Visible in Chemistry



Making Thinking Visible in Chemistry

Part One

Introduction

Making Thinking Visible in Chemistry

1. Introduction

“If children can’t learn the way that we teach,
then maybe we should teach the way that
they learn.”

Ignacio Estrada

“We should teach children how to think, not what
to think.”

Margret Mead

“The best teachers are those who show you
where to look, but don’t tell you what to see.”

Alexandra K. Trenfor

Making Thinking Visible in Chemistry

1. Introduction

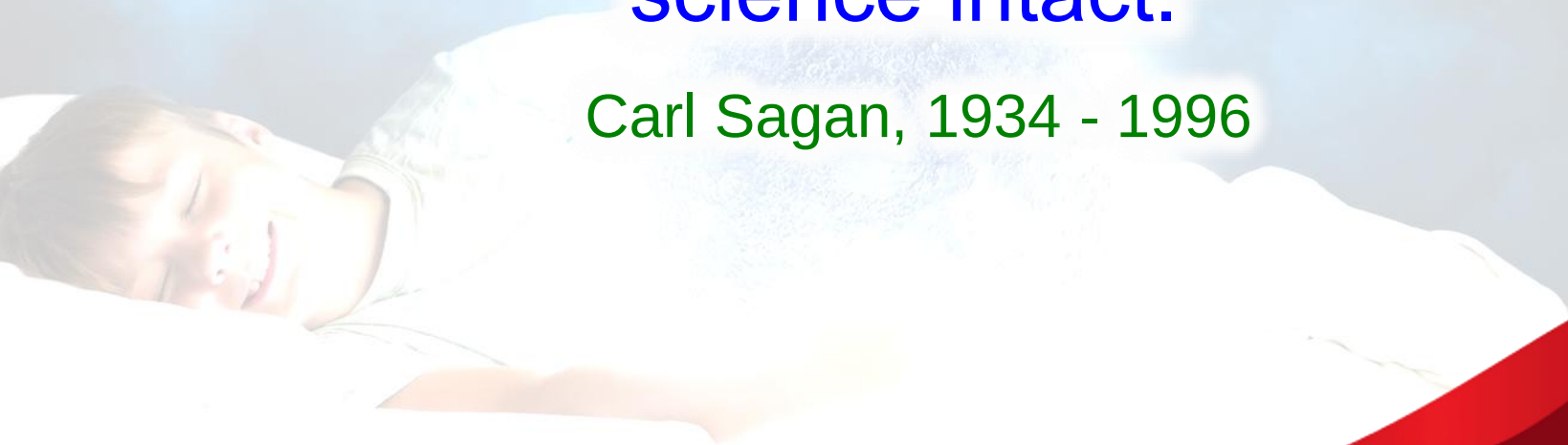


Making Thinking Visible in Chemistry

1. Introduction

“Every kid starts out as a natural born scientist, and then we beat it out of them. A few trickle through the system with their wonder and enthusiasm for science intact.”

Carl Sagan, 1934 - 1996



Making Thinking Visible in Chemistry

1. Introduction



Making Thinking Visible in Chemistry

1. Introduction

Are the students in our
classrooms really *doing*
Science...

...or are they just *doing the*
lesson?

Making Thinking Visible in Chemistry

1. Introduction

- From your experience, why is Chemistry difficult to teach?

Making Thinking Visible in Chemistry

1. Introduction

- Chemical knowledge has been developed by Chemists for use by Chemists.
- As a consequence, chemical knowledge is not automatically useful for school students.
- The knowledge of Chemistry needs to be transformed to be useful in schooling.

• Fensham, 2005.

Making Thinking Visible in Chemistry

1. Introduction

- From your experience, why is Chemistry difficult to learn?

Making Thinking Visible in Chemistry

1. Introduction

- Students' experience of learning science at school:
 - Transmissively taught (soaked up like a sponge).
 - Boring and irrelevant content (compared to the students' lives).
 - Difficult to learn (compared to other subjects).

• Fensham, 2005.

Making Thinking Visible in Chemistry

1. Introduction

- In your opinion, what purpose does Chemistry have in compulsory education?

Making Thinking Visible in Chemistry

1. Introduction

- Public understanding of Chemistry:
 - Bottled water.
 - Clean energy.
 - Climate change and environment.
 - Contents labelling (ingredients).
 - Cosmetics advertisements.
 - Organic food.
 - Supermarket “best before” dates.

• Fensham, 2005.

Making Thinking Visible in Chemistry

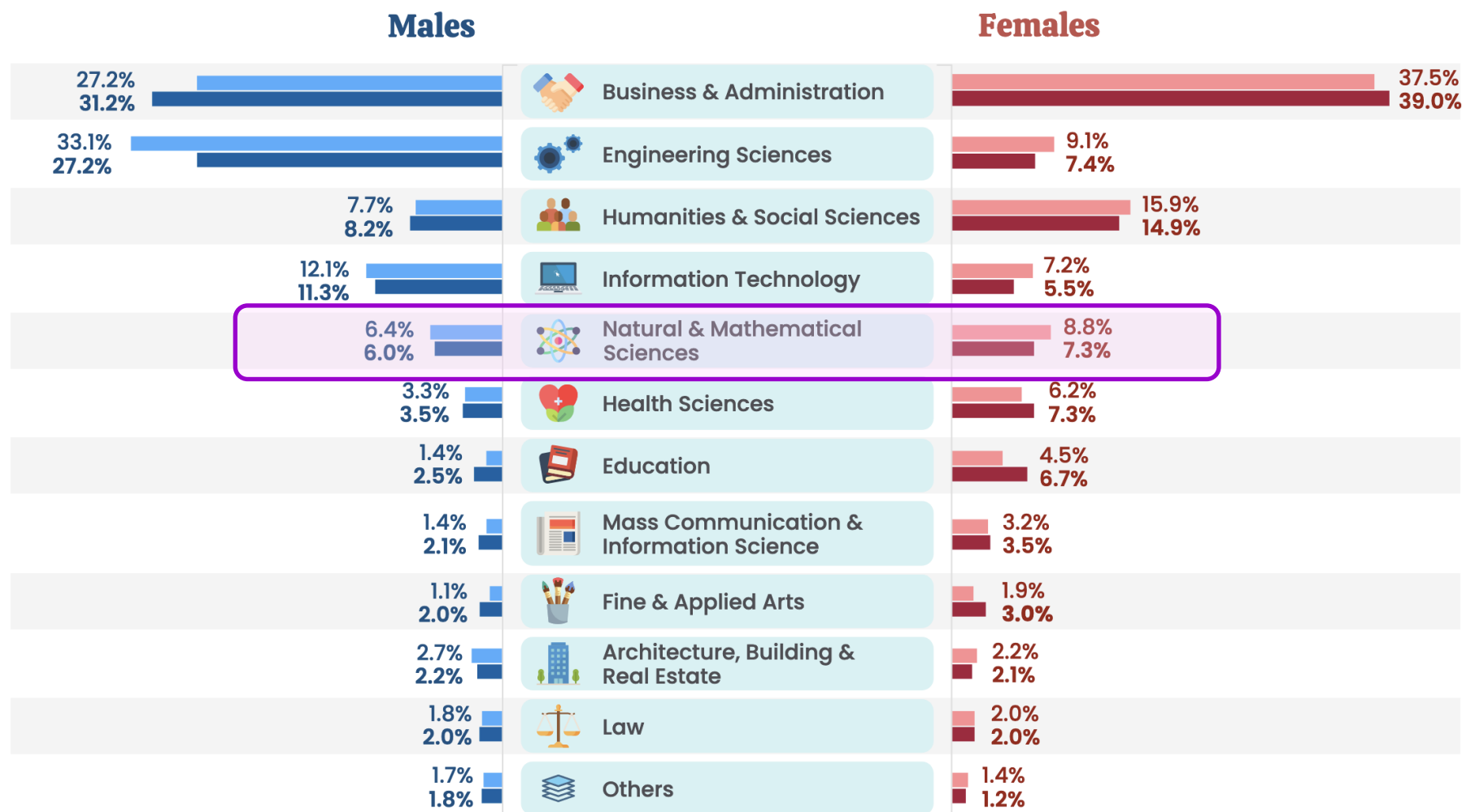
1. Introduction



RESIDENT UNIVERSITY GRADUATES BY FIELD OF STUDY AND SEX

Business and administration was the top field of study among university graduates.

● Male (2010) ● Female (2010)
● Male (2020) ● Female (2020)



Making Thinking Visible in Chemistry

1. Introduction

- The challenge is that only a small percentage of our students will become creators of new Scientific knowledge (Scientists) or engage in Science related careers (e.g. Pharmacists).

- Science is an essential and unique discipline.

→ Science is a body of knowledge:

Facts, concepts theories and laws.

→ Science is a way of thinking:

Curiosity, imagination, reasoning, objectivity, scepticism, cause and effect.

→ Science is a way of investigating:

Inquiring, observing, experimenting, concluding.

- McComas, 2017.

Making Thinking Visible in Chemistry

1. Introduction

- Reasons for Teaching Science:
Students See Themselves...

1. As *creators* of new Scientific knowledge (Scientists).
2. In Science *careers* (e.g. Doctors and Veterinarians).
3. As *citizens* who use Science in decision making.
4. As *consumers* who apply their Science knowledge.
5. As *critics* of the misuse of Science.
6. As *connoisseurs* who enrich their lives with Science.
7. As *collaborators* with Scientists.
8. As those who can make *connections*
beyond Science.

- McComas, 2017.

Explore The 2021 Survey Data

STEM Equity & Education

Q11
What do you believe are the top barriers, if any, standing in the way of students currently accessing a strong science, technology, engineering or math (STEM) education within your country? Select top three.

Q12
Students would be more inspired to pursue science, technology, engineering or math (STEM) if... Select top three.

Q13
How much do you agree or disagree with each of the following statements?

Q14
To what extent do you believe the following entities should play a role in supporting students' science, technology, engineering or math (STEM) education?

Q15
How much do you agree or disagree with the following statement: It is important to increase diversity and inclusion in science, technology, engineering and math (STEM)

Students would be more inspired to pursue science, technology, engineering or math (STEM) if... Select top three.

FILTERS

17,090 respondents

Science was taught in a more engaging way 44%

Students had a better understanding of the different career opportunities in science 43%

Students could see how science provides them with a platform to make the world better 41%

Schools invested more in science curricula 40%

Science was more relatable to students' everyday lives 38%

There were more diverse role models in STEM for students to look up to 27%

Influential figures who students admire advocated for STEM 21%

Students' family and friends also were involved in STEM 19%

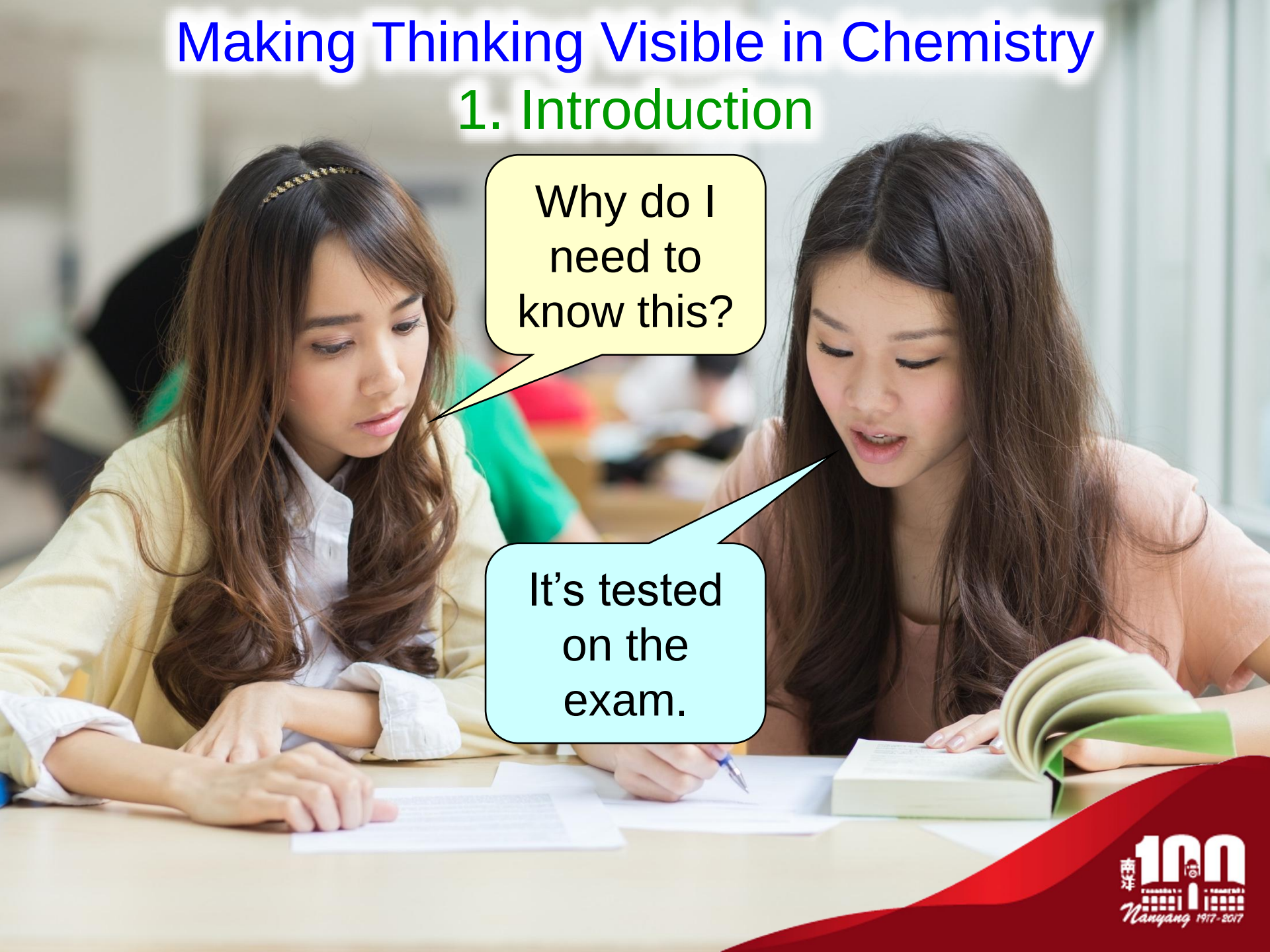
Making Thinking Visible in Chemistry

1. Introduction



Making Thinking Visible in Chemistry

1. Introduction

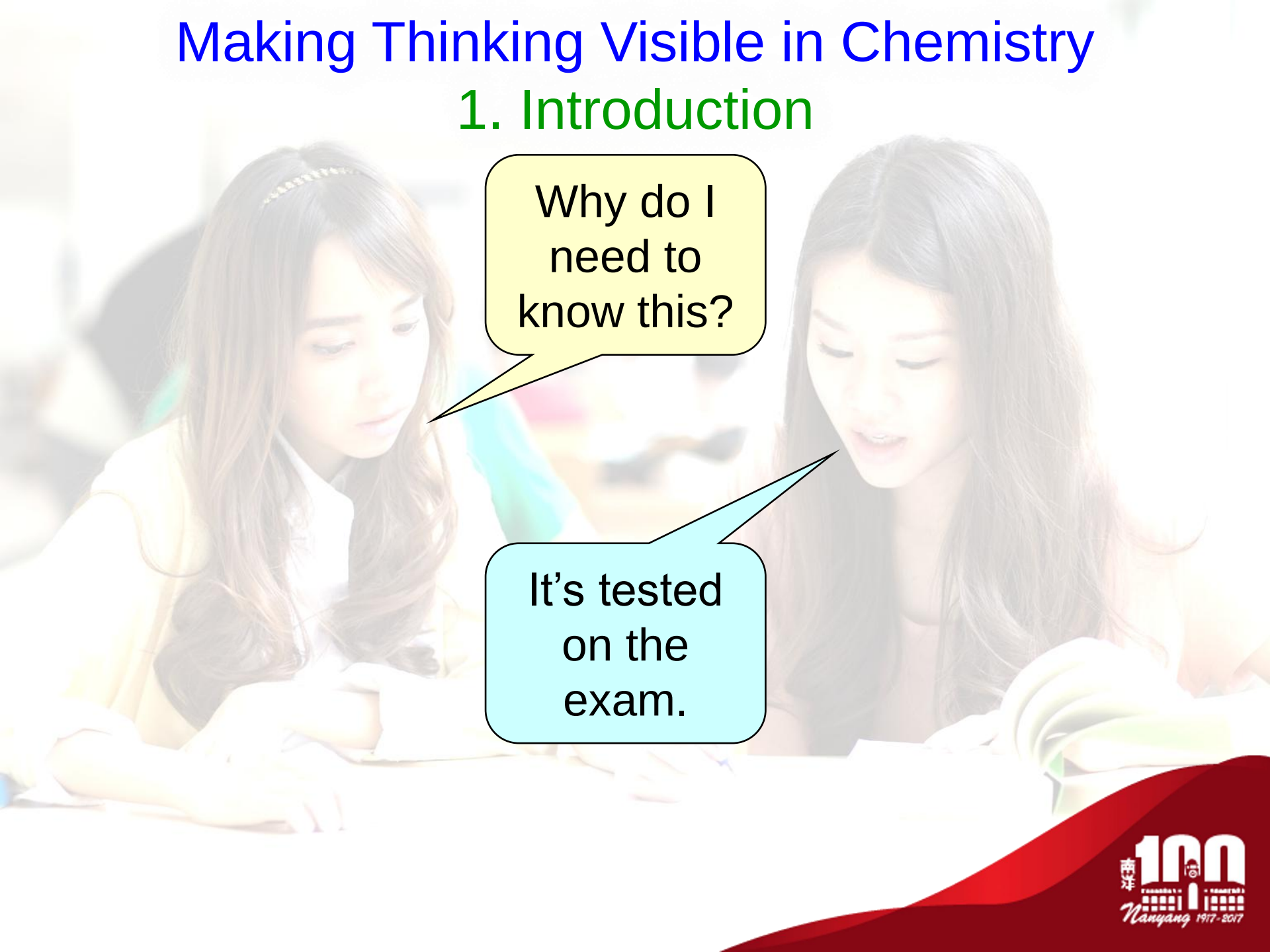


Why do I
need to
know this?

It's tested
on the
exam.

Making Thinking Visible in Chemistry

1. Introduction



Why do I
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It's tested
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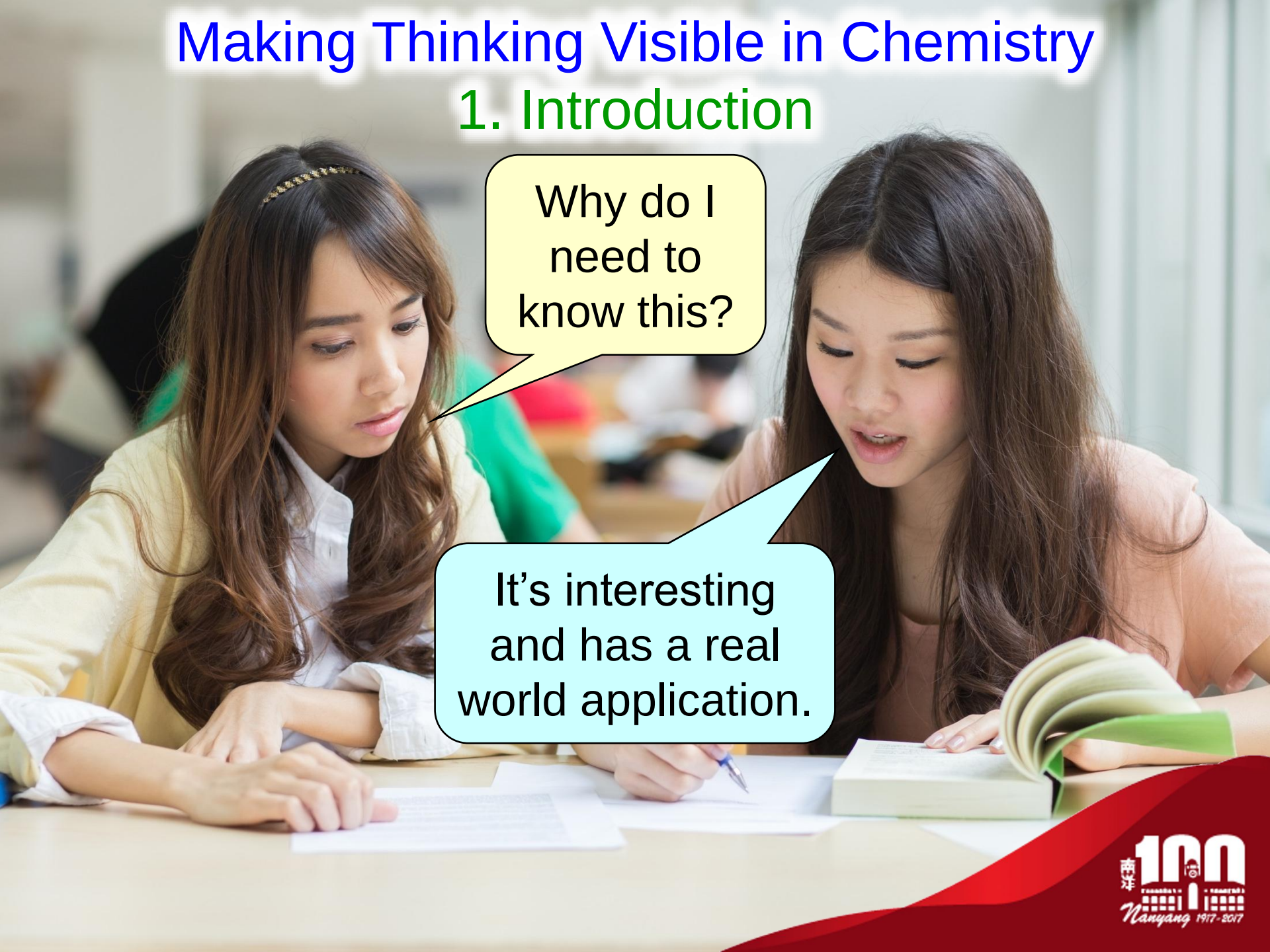
Making Thinking Visible in Chemistry

1. Introduction

Let's try that again...

Making Thinking Visible in Chemistry

1. Introduction

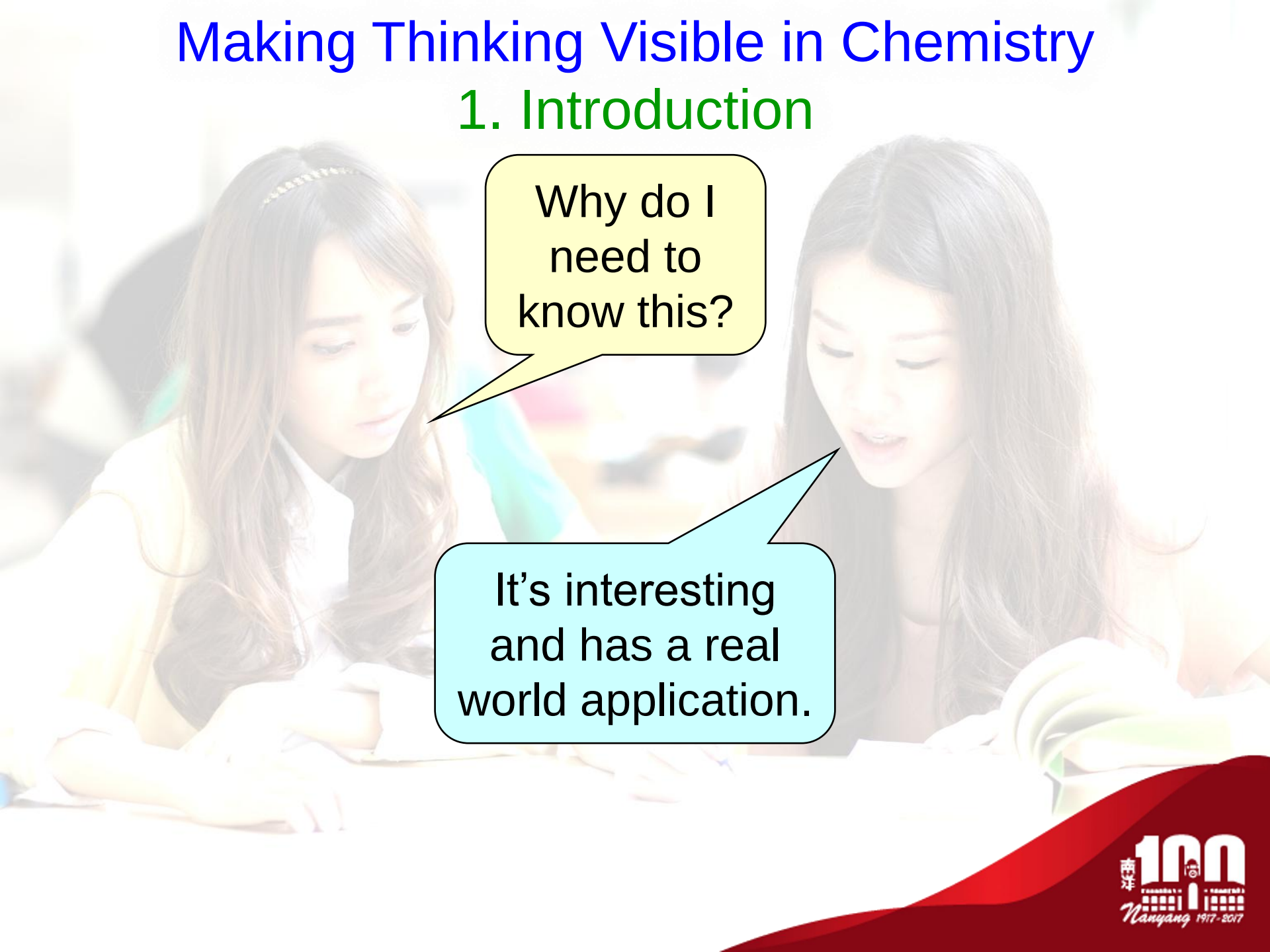


Why do I
need to
know this?

It's interesting
and has a real
world application.

Making Thinking Visible in Chemistry

1. Introduction

A background image of two female students with long dark hair, wearing white lab coats, looking down at a book or document on a table. A yellow speech bubble points to the student on the left, and a light blue speech bubble points to the student on the right.

Why do I
need to
know this?

It's interesting
and has a real
world application.

Making Thinking Visible in Chemistry

1. Introduction

- A key issue with teaching and learning Chemistry is the abstract nature of the subject. Teachers can demonstrate, and students can observe, the consequence of a chemical reaction, *e.g.* a change in temperature or the production of a gas, but it is impossible to observe the actual particles as they react.

Making Thinking Visible in Chemistry

1. Introduction

- Teachers struggle with explaining what cannot be observed and students become frustrated as they try to imagine what might be happening at a molecular level. This combination has the potential to create misconceptions in the mind of the student and a difficulty in learning the subject.

Making Thinking Visible in Chemistry

1. Introduction

- Learning is a consequence of thinking (Clark and Linn, 2003). Learning improves when students are able to think through the concepts that they are studying, a process that takes time and energy and requires varied activities and many opportunities to make connections.

Making Thinking Visible in Chemistry

1. Introduction

- In addition, good thinking (and hence learning) requires students to be open-minded, curious, sceptical and imaginative (Perkins and Ritchhart, 2004). Without these characteristics, good thinking will not take place and only shallow learning will occur (Hattie and Yates, 2014).

Making Thinking Visible in Chemistry

1. Introduction

- In order for students to learn Chemistry, they must be able to think through the concept that they are studying, but if they are unable to imagine what is taking place at a molecular level, shallow learning will occur and misconceptions will accumulate. It is therefore important for Chemistry students to make their thinking and learning visible so that they can reflect on their own work and so that it can be evaluated by their peers and their teachers.

Making Thinking Visible in Chemistry

1. Introduction

- In this workshop, a variety of strategies will be shared that encourage *both teachers and students* to make their thinking visible.

Making Thinking Visible in Chemistry

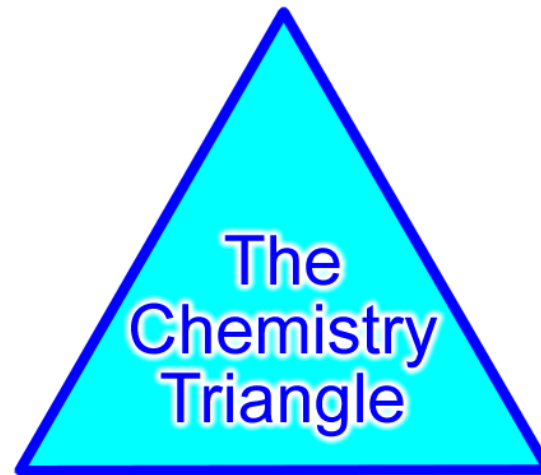
1. Introduction

- “In learning abstract science concepts, if teachers could use pedagogical approaches that allow students to visualise the concepts, this will prompt students to have a better understanding of the concepts.”

- Karpudewan *et al.*, 2017.

Making Thinking Visible in Chemistry

1. Introduction



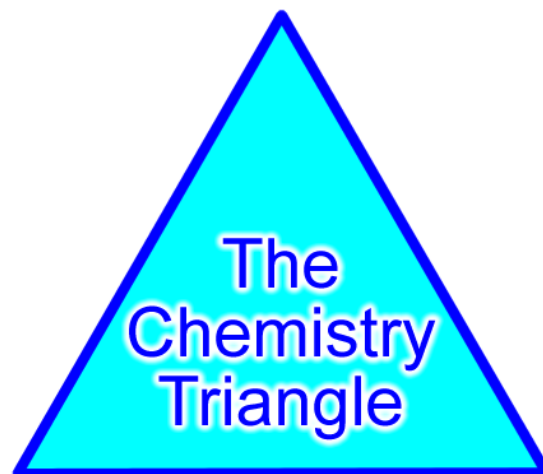
- Johnstone, 1991.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic
(Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.



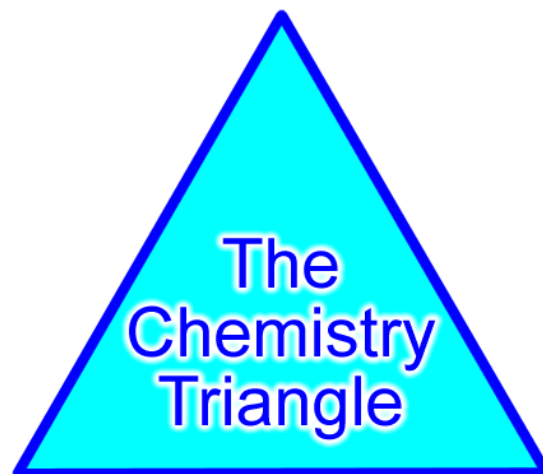
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Making Thinking Visible in Chemistry

1. Introduction

Macroscopic
(Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.



Sub-microscopic
(Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

- Johnstone, 1991.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic
(Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The
Chemistry
Triangle

Sub-microscopic
(Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

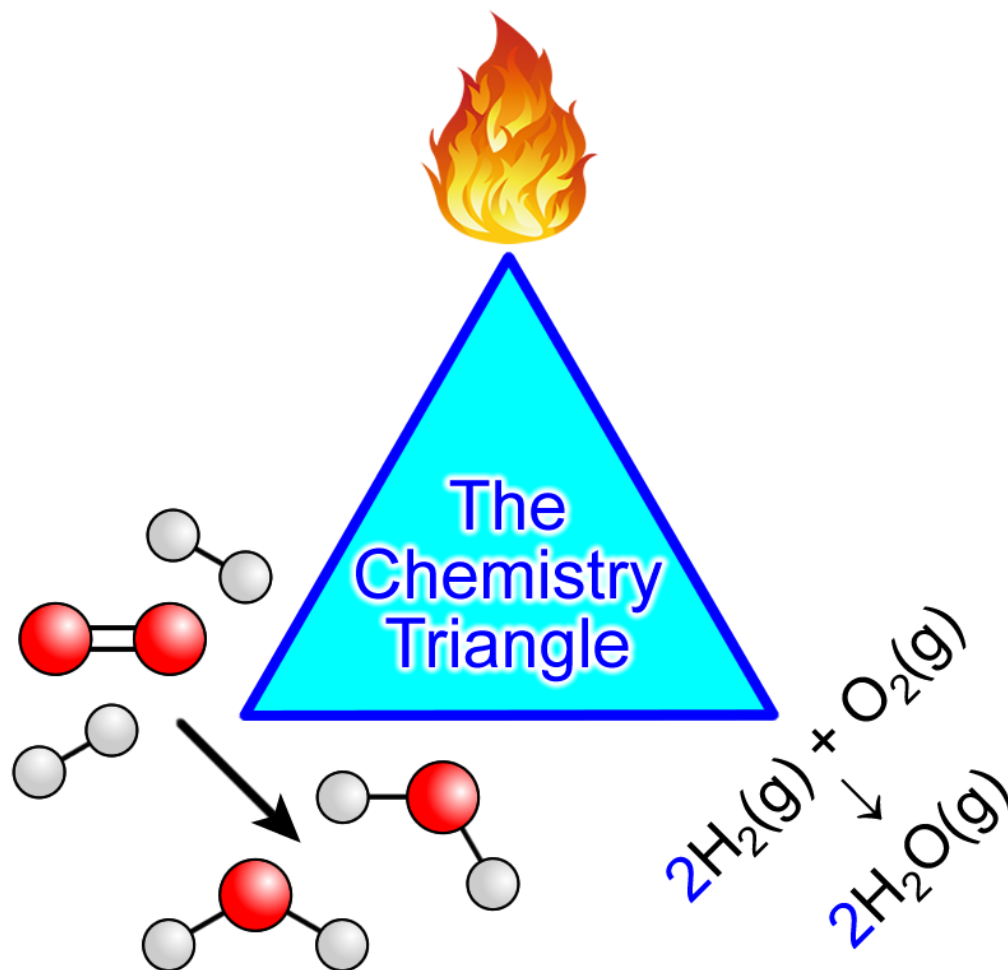
Representational
(Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- Johnstone, 1991.

Making Thinking Visible in Chemistry

1. Introduction



• Johnstone, 1991.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic (Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The Chemistry Triangle

Sub-microscopic (Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

Representational (Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- Johnstone's *Chemistry Triangle* illustrates his proposal that students must learn *three different domains* of Chemistry at once.
- Beyond that, to be successful at Chemistry, students must see the *connections* and *relationships* between the three domains.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic (Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The Chemistry Triangle

Sub-microscopic (Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

Representational (Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- The *sub-microscopic domain* of Chemistry is probably the part of the discipline with which students have the most problems – trying to visualise how particles are arranged in a liquid, what changes take place when a salt dissolves in water, and how atoms of the different elements bond together to form compounds.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic (Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The Chemistry Triangle

Sub-microscopic (Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

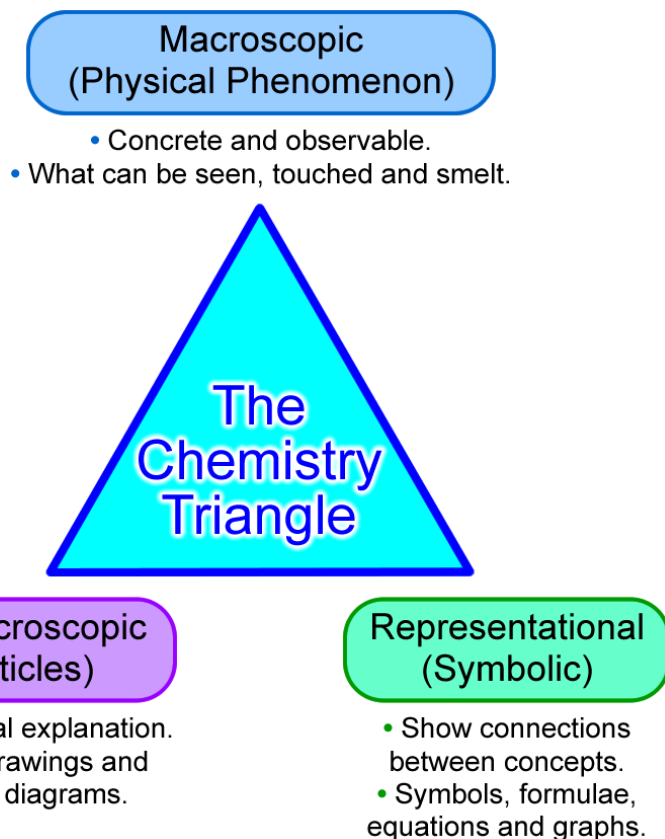
Representational (Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- It is not always necessary to teach all three domains of Chemistry to students at once – but students who have some knowledge and understanding of all three domains are more likely to have a deeper appreciation of the discipline.

Making Thinking Visible in Chemistry

1. Introduction



- Teaching Chemistry will most often start at the *macroscopic level* – investigating Chemistry through what can be observed and measured (this is the origin of Chemistry).
- At this point, the teacher will often take the opportunity to relate Chemistry to the students' everyday lives, making connections to what they are already familiar with.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic
(Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The
Chemistry
Triangle

Sub-microscopic
(Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

Representational
(Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- After the macroscopic domain, most teachers and students will proceed to represent their observations using symbols, formulae, equations and graphs.
 - Historically, this is how Chemists worked in order to understand the natural world, some proposing theories about the sub-microscopic domain based upon their observations.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic (Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.

The Chemistry Triangle

Sub-microscopic (Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

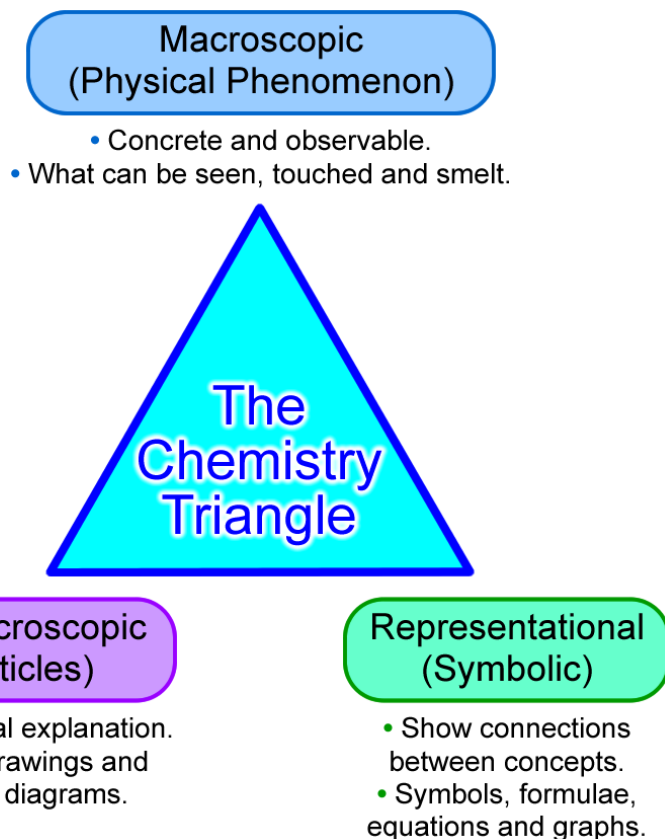
Representational (Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- The sub-microscopic domain is beyond observation in a secondary school environment. Students can only observe and record the macroscopic outcome of interactions at a sub-microscopic level.
- For some individuals, and for some topics in Chemistry, this may be sufficient.

Making Thinking Visible in Chemistry

1. Introduction



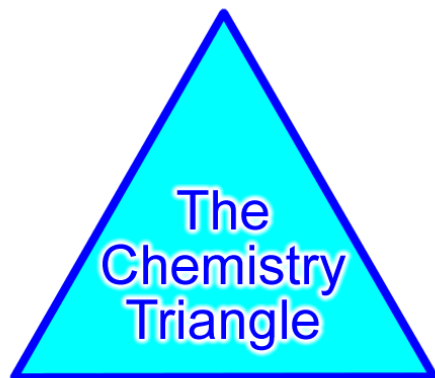
- However, an explanation of the physical phenomenon, e.g. *why* an increase in temperature increases the rate of a chemical reaction, must be articulated at a sub-microscopic level.
- What cannot be directly observed is open to misinterpretation. This is where misconceptions (which may be difficult to unlearn) start to manifest themselves.

Making Thinking Visible in Chemistry

1. Introduction

Macroscopic
(Physical Phenomenon)

- Concrete and observable.
- What can be seen, touched and smelt.



Sub-microscopic
(Particles)

- Conceptual explanation.
- Model drawings and concept diagrams.

Representational
(Symbolic)

- Show connections between concepts.
- Symbols, formulae, equations and graphs.

- In summary, it is important for teachers to make their thinking, reasoning and explanations as clear as possible. This is to avoid any misconceptions developing in the minds of their students.
- It is also very important for students to make their thinking visible so that their teachers (and peers) can assess whether their understanding of a particular concept is correct.

Making Thinking Visible in Chemistry

1. Introduction

- Students endeavour to make their knowledge and understanding of Chemistry visible on their *summative assessments*.
- Teacher should model good thinking routines for their students and use subtle *formative assessments* that encourage students to make their thinking visible.

Making Thinking Visible in Chemistry



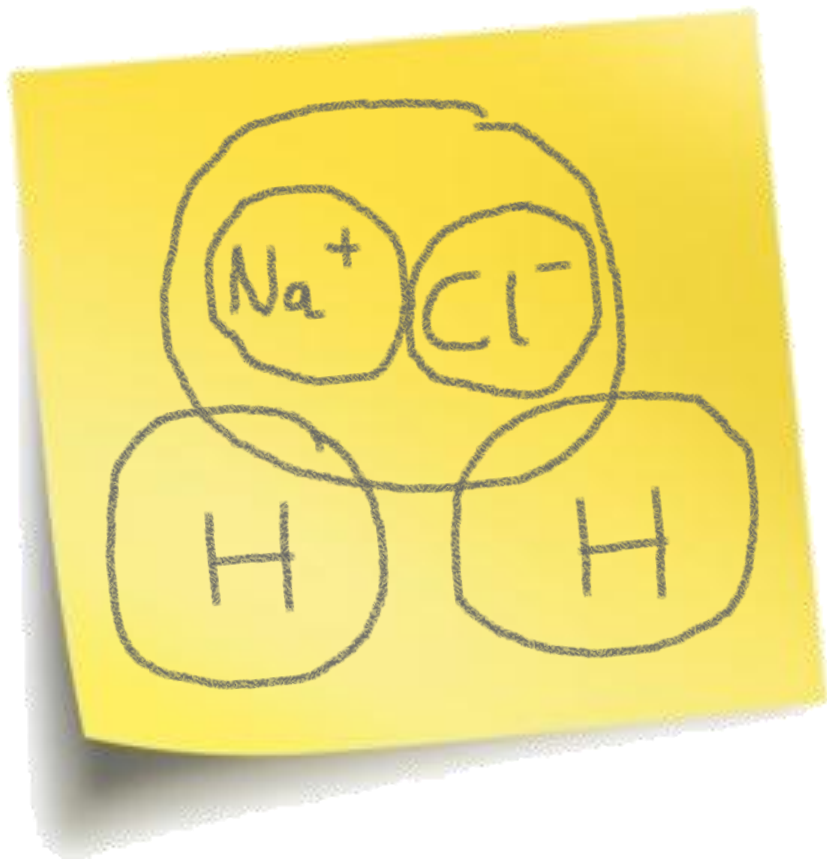
Part Two

Examples of How
Teachers and Students
Can Make Their
Thinking Visible

Making Thinking Visible in Chemistry

2. Examples of Misconceptions

Students' Understanding of Aqueous Sodium Chloride



- Students were asked to draw what they thought NaCl looks like once it has been dissolved in water.
- One student drew a sodium ion and a chloride ion *inside* a water molecule, illustrating the misconception that NaCl is literally “dissolved *in* water”.

Making Thinking Visible in Chemistry

2. Examples of Misconceptions

Students' Understanding of a Particle in a Vacuum



- Students were asked to draw how they thought a single gaseous particle moves in a vacuum.
- Some students drew the particle moving randomly instead of a straight line. They believed the particle will move randomly, even when there are no other particles to collide with.

Making Thinking Visible in Chemistry

2. Examples of Misconceptions

Effect of Bonding on Physical Properties

methanamine	-6.6
propan-1-amine	47

- (i) Predict the boiling point of butan-1-amine.

[1]

120°C ~~X~~ Too high! 0

- (ii) Explain why the boiling point of butan-1-amine is different as compared to the rest of the amines.

[2]

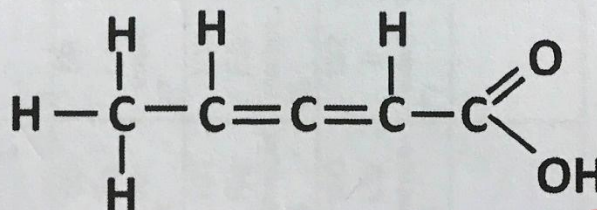
* Covalent bonds
are within the
molecule,
Van der Waals forces
between the

With the increase in molecular mass, there would be a
stronger covalent bond between the molecules and thus require
greater energy to break them apart therefore buta-1-amine
has a much higher boiling point as compared to the rest of the amines.

1

- 3 An unsaturated organic compound X, of molecular formula $C_5H_6O_2$ has the structural formula as shown below.

molecules.

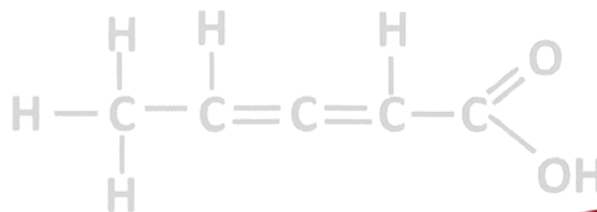


Making Thinking Visible in Chemistry

2. Examples of Misconceptions

Effect of Bonding on Physical Properties

- Students often use the wrong terms when describing chemical bonding. For example, they say that diamond has, “giant covalent bonds” when they should say that diamond has a, “giant covalent structure”.
- Is this simply a careless mistake, or do some students really think that the covalent bonds in diamond are much larger than the covalent bonds found between the atoms of other non-metallic elements?



(b) Th Making Thinking Visible in Chemistry

2. Examples of Misconceptions Effect of Bonding on Physical Properties

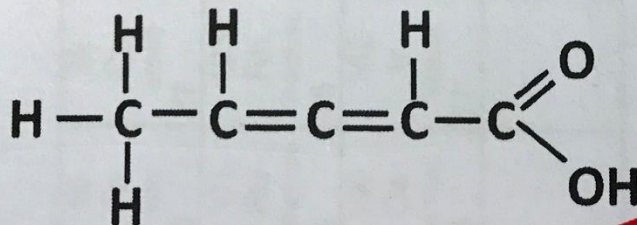
- (i) Predict the boiling point of butan-1-amine. [1]

86 °C.

- (ii) Explain why the boiling point of butan-1-amine is different as compared to the rest of the amines. [2]

It has a larger relative molecular mass, & large surface area...
and stronger Van der Waals forces of attraction
holding the atoms together, and
therefore has a higher boiling point.

An unsaturated organic compound X, of molecular formula $C_5H_6O_2$ has the structural formula as shown below.



(b)

Th

Making Thinking Visible in Chemistry

2. Examples of Misconceptions

Effect of Bonding on Physical Properties

(i) Predict the boiling point of butan-1-amine.

[1]

85 °C

(ii) Explain why the boiling point of butan-1-amine is different as compared to the rest of the amines.

[2]

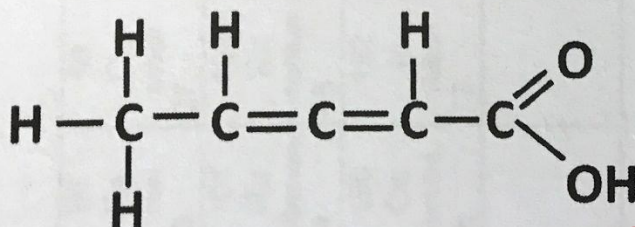
Butan-1-amine ~~is~~ consists of more carbon ^{atoms} molecules

and thus there are more intermolecular forces of attraction ^{between} ~~between~~ ₁ molecules

~~causing th~~ Thus, more amount of energy is needed

to break the intermolecular forces of attraction between molecules and the boiling point is thus higher.

An unsaturated organic compound X, of molecular formula $C_5H_6O_2$ has the structural formula as shown below.



Making Thinking Visible in Chemistry

3. Harvard Project Zero Thinking Routines I Used to Think... ..(But) Now I Think

- This is a popular thinking routine that can be used to show how a student's understanding of a topic has changed as a result of teaching or experience.
- The student begins by describing what they used to think before they learn something new by, for example, watching a video, conducting an experiment or participating in a class discussion.
- Next, the student describes how their thinking has changed as a result of the new information. It is useful to probe further and discover what impact this change has had on their understanding of the topic.

Making Thinking Visible in Chemistry

3. Harvard Project Zero Thinking Routines I Used to Think... ..(But) Now I Think

- A student reflects upon what they think an acid is based upon what they have read in the news and seen in films:

“I used to think that acids were dangerous, corrosive liquids that dissolved everything.”

- The student reflects upon what they think an acid is after studying the unit on acids, bases and salts:

“Now I think that acids are chemicals that produce hydrogen ions. They can be neutralised by bases, and some acids are even safe enough to eat.”

Making Thinking Visible in Chemistry

3. Harvard Project Zero Thinking Routines I Used to Think... ..(But) Now I Think

- A student reflects upon what they think an atom is after studying the basic model of atomic structure:

“I used to think that electrons went around the nucleus of the atom in circles.”

- The student reflects upon what they think an atom is after completing an enrichment course on atomic orbitals:

“Now I think that electrons move around the nucleus in orbitals, and their arrangement is controlled by certain rules.”

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles



- A single M&M's® represents a single atom. M&M's® of different colours represent atoms of the different chemical elements.

Making Thinking Visible in Chemistry

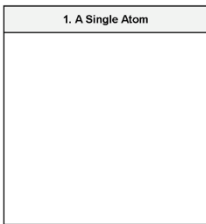
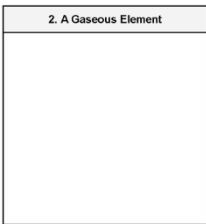
4. Using M&M's® to Represent Particles

  **Chem!stry** Name: ()
Class:
Date: / /

Modelling Atoms, Elements, Compounds and Mixtures in the Solid, Liquid and Gaseous States

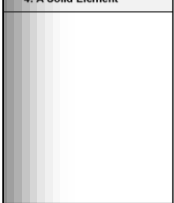
Introduction:
Physical and mathematical models are often used by scientists to help them understand abstract and complex ideas. For example, scientists model the behaviour of particles that are too small to visualise – even with the most powerful electron microscopes. In this activity you will use M & M's® or Smarties® to model the arrangement of atoms, elements, mixtures and compounds in the solid, liquid and gaseous state.

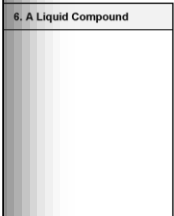
Instructions:
A single M & M's® or Smartie® represents a single atom. Working individually, arrange the M & M's® or Smarties® in the various boxes to model the substance that is being described. You should take digital photographs of your models to record your work. The photographs should then be uploaded – along with a brief description – and shared on to your class *Chemistry* blog so that your peers can evaluate and comment on them.

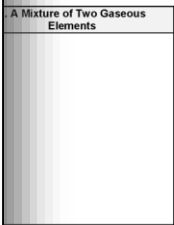
1. A Single Atom	2. A Gaseous Element
	

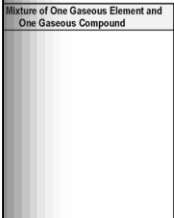
Notes:
.....
.....
.....

1

4. A Solid Element


6. A Liquid Compound


A Mixture of Two Gaseous Elements


Mixture of One Gaseous Element and One Gaseous Compound


2

3. What are the strengths and weaknesses of the models used in this activity?
2. Beyond Chemistry, give examples of how models are used to represent ideas in other subjects.

3

- Students complete a worksheet on which they arrange M&M's® to represent elements, compounds and mixtures as solids, liquids and gases.
- Students can photograph their answers and upload into a shared document.

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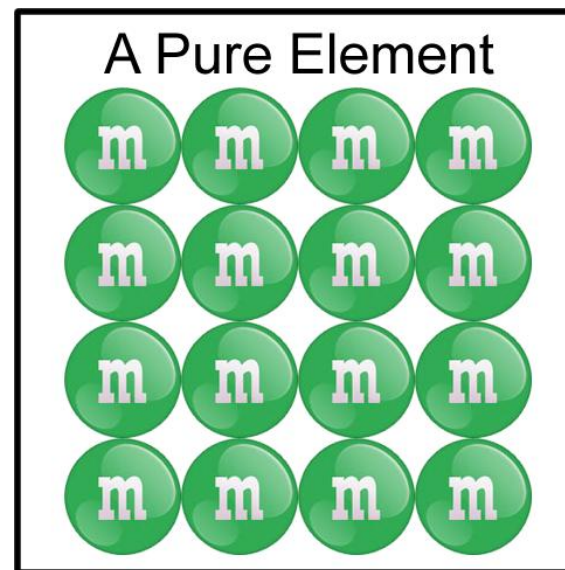
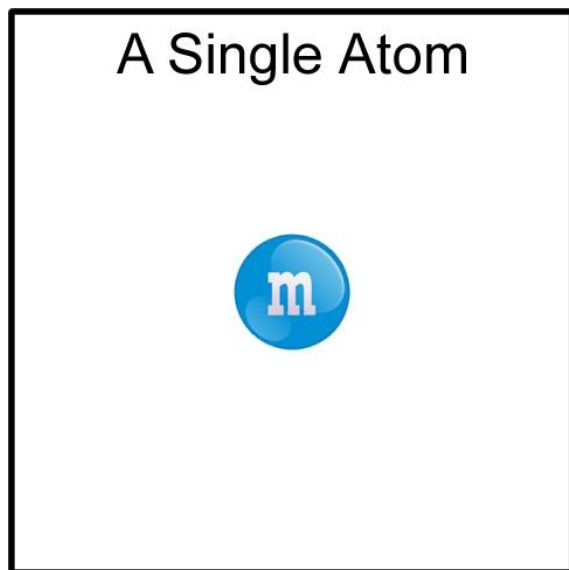
4. Using M&M's® to Represent Particles

A Single Atom

A Pure Element

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles



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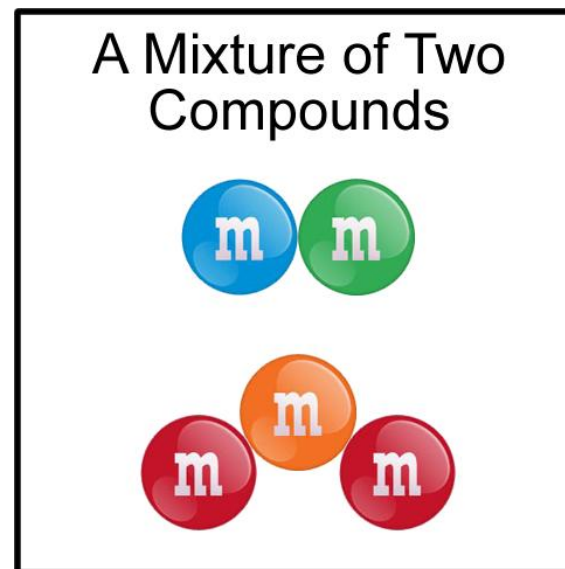
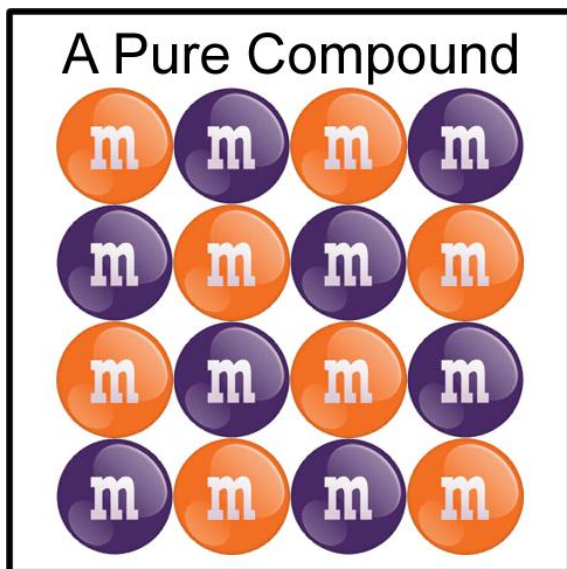
4. Using M&M's® to Represent Particles

A Pure Compound

A Mixture of Two
Compounds

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles



Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles

Pure Element (Solid)

Pure Element (Liquid)

Pure Element (Gas)

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles

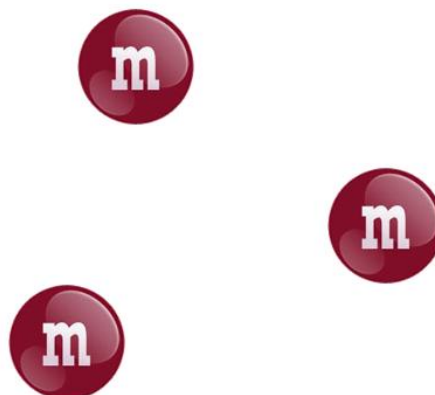
Pure Element (Solid)



Pure Element (Liquid)

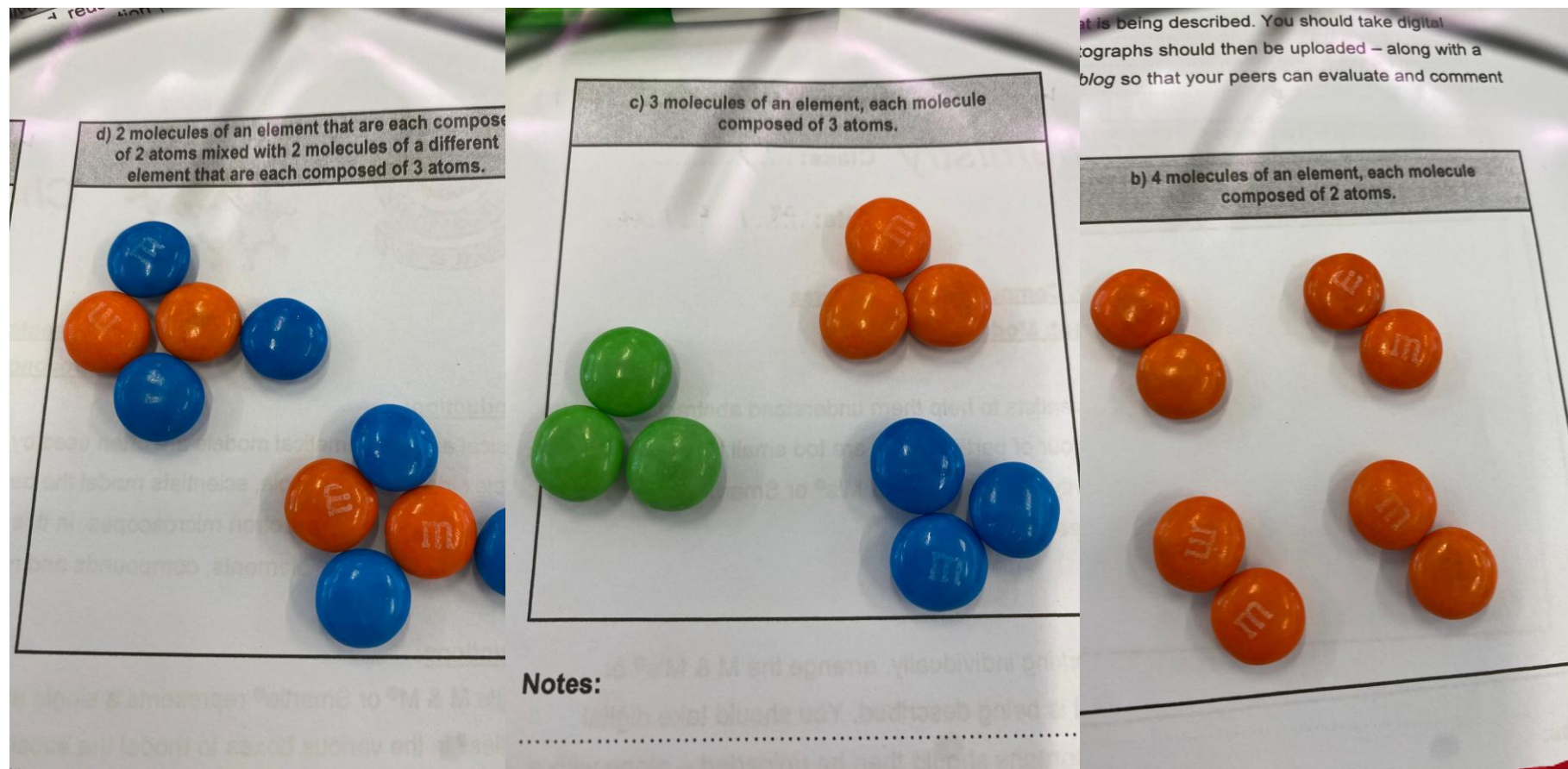


Pure Element (Gas)



Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles



- Can you spot any mistakes in this student's work?

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles

- Different M&M's® are available on the market, e.g. milk chocolate, peanut and almond.
- These different M&M's® can be used to represent isotopes of a chemical element. Students can calculate the average mass of a single M&M's® and apply this to the concept of relative atomic mass.




An Introduction to Science
Determining the Average Atomic Mass

• It is anticipated that by completing this exercise, you will be able to use objects to model complex concepts. For example, you can use the mass of a single M & M candy. Secondly, you can use the atomic mass of a chemical element.

Question One:
Six different types of M & M's are known to exist. What is the scientific importance of M & M's being known to exist?
How is this information determined?
List the possible characteristics of an M & M's candy based on observation and experiment.

Question Two:
The table on page 2 presents some essential data for the calculation of the average mass of a single M & M. One important observation is that the mass of a single M & M is not the same for all types. Use the data provided in the table on page 2, making any necessary calculations to determine the average mass of a single M & M.

Question Three:
Complete the calculation column in the table below, giving your answers to one decimal place:

Type:	Illustration:	Information:	Calculation:
Almond		Mass of one packet = 37.1 g Modification: Number of M & M's in one packet = 13 Modification:	Average mass of one M & M =
Crispy		Mass of one packet = 34.0 g Modification: Number of M & M's in one packet = 28 Modification:	Average mass of one M & M =
Dark Chocolate		Mass of one packet = 47.9 g Modification: Number of M & M's in one packet = 57 Modification:	Average mass of one M & M =
Milk Chocolate		Mass of one packet = 40.0 g Modification: Number of M & M's in one packet = 45 Modification:	Average mass of one M & M =
Peanut		Mass of one packet = 40.0 g Modification: Number of M & M's in one packet = 16 Modification:	Average mass of one M & M =
Peanut Butter		Mass of one packet = 46.2 g Modification: Number of M & M's in one packet = 28 Modification:	Average mass of one M & M =

More to explore: What is the difference between decimal places and significant figures? When answering numerical questions how many decimal places or significant figures should you give your answer to?

2

Making Thinking Visible in Chemistry

4. Using M&M's® to Represent Particles



Making Thinking Visible in Chemistry

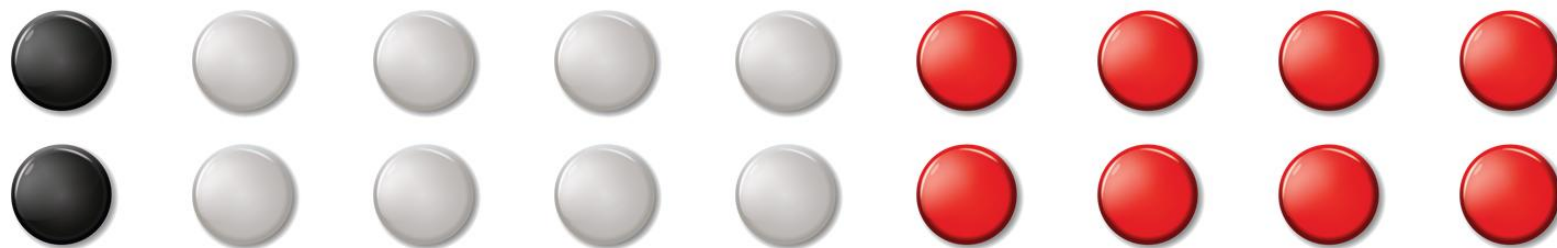
4. Using M&M's® to Represent Particles

- A mixture of sweets of different sizes can be used to illustrate the principle of filtration.
- The mixture of sweets, some large and some small, are placed inside a clear plastic box.
- Students are asked how they could quickly and easily separate the mixture of sweets!
- The solution is to use a sharp knife to cut several holes in the box, big enough for the small sweets to fit through, but not big enough for the large sweets to fit through.
 - What is the filter paper? What is the filtrate? What is the residue?

Making Thinking Visible in Chemistry

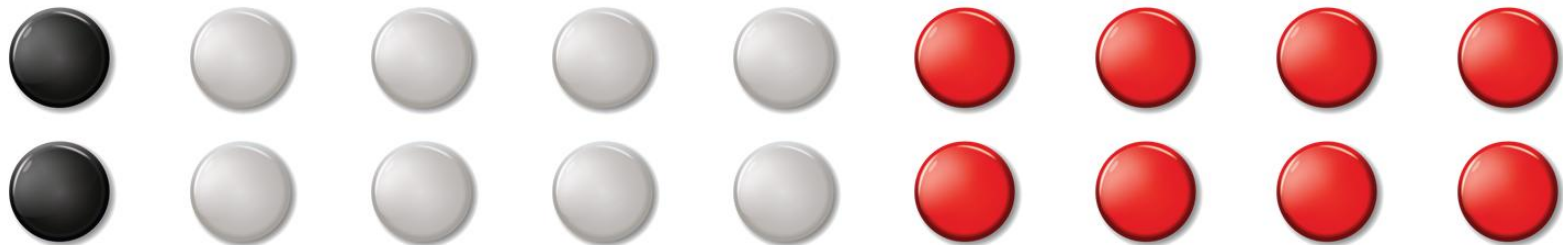
5. Using Magnets to Represent Particles

- Different coloured button magnets can be used on magnetic white boards to make several concepts more clearly visible to students. The magnets can be used to represent the electrons in dot-and-cross diagrams when discussing chemical bonding. The magnets can also be used to represent atoms / ions while balancing chemical equations.



Making Thinking Visible in Chemistry

5. Using Magnets to Represent Particles



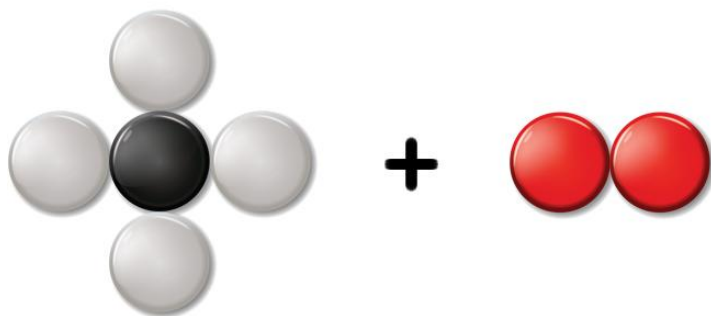
Making Thinking Visible in Chemistry

5. Using Magnets to Represent Particles



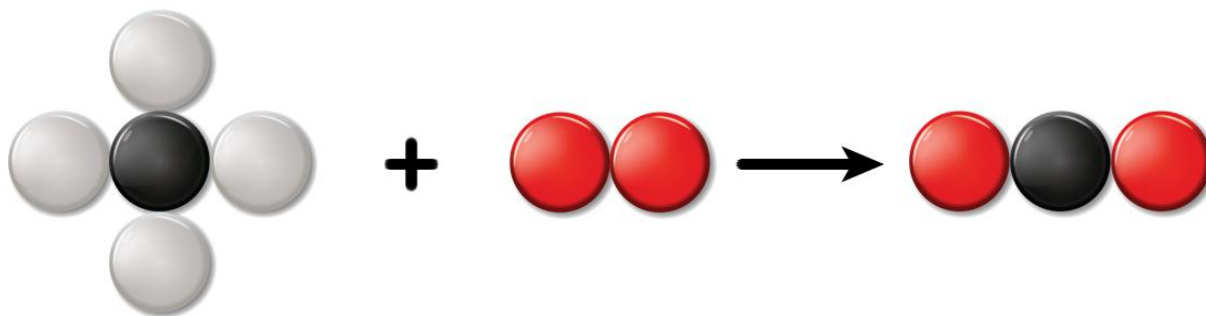
Making Thinking Visible in Chemistry

5. Using Magnets to Represent Particles



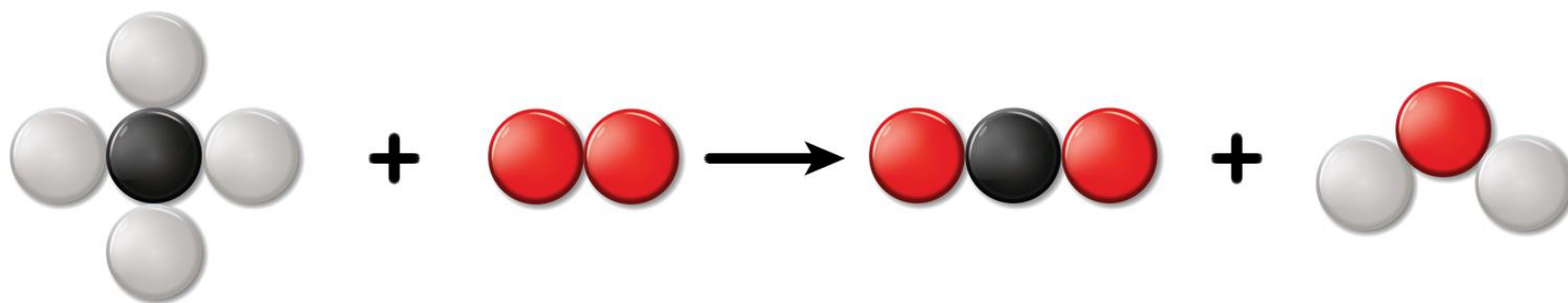
Making Thinking Visible in Chemistry

5. Using Magnets to Represent Particles



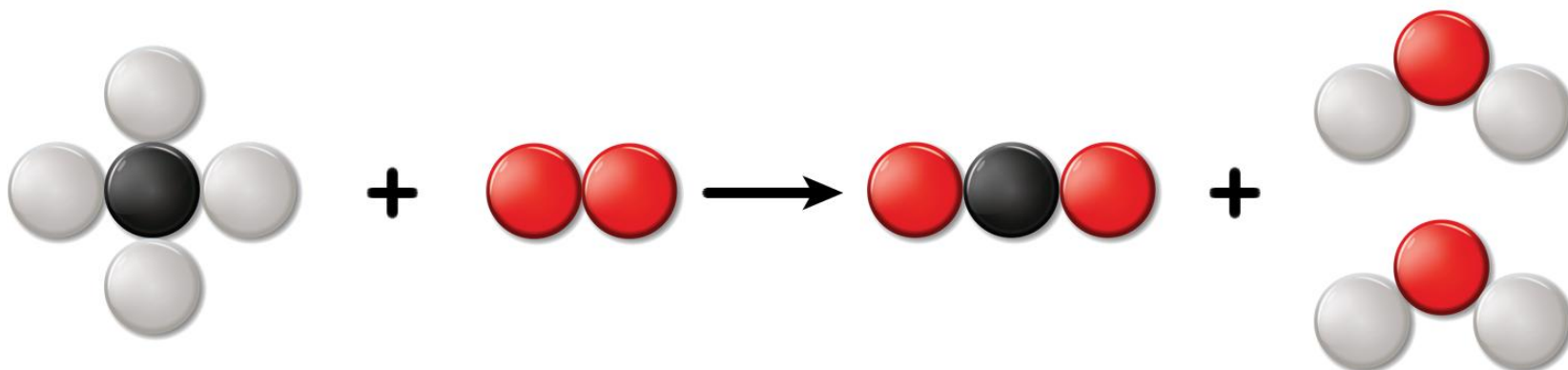
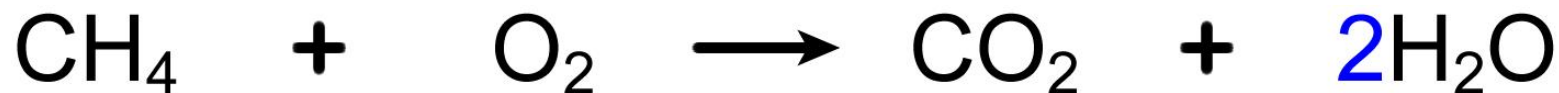
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5. Using Magnets to Represent Particles



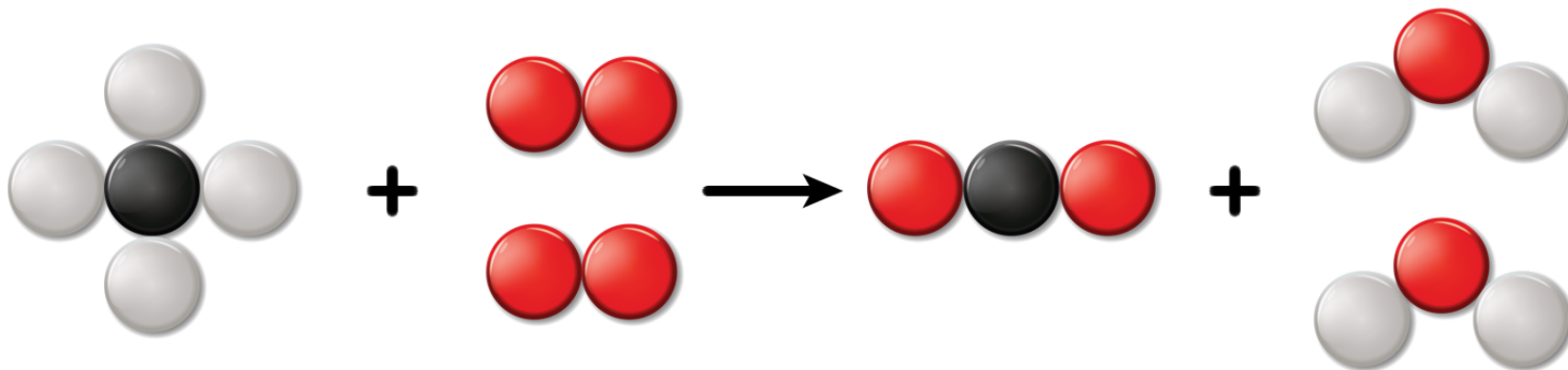
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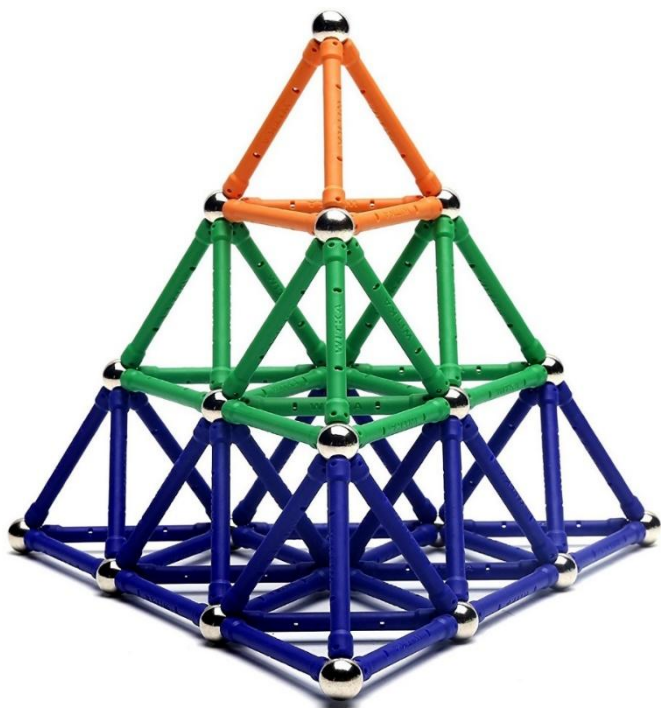
Making Thinking Visible in Chemistry

5. Using Magnets to Represent Particles



Making Thinking Visible in Chemistry

6. Using Magnets to Represent Shapes of Molecules



- Ball bearings and magnets allow students to investigate and demonstrate their understanding of valence shell electron pair repulsion theory (VSEPR).
- Unlike conventional modelling kits, magnets attach to ball bearings and can be adjusted to point in *any* desired direction.
- Students can easily add bonds and adjust bond angles until regions of high electron density are moved away from each other.

Making Thinking Visible in Chemistry

7. Pictionary – Drawing and Sketching Ideas



- Students work in small groups of two – three.
- Students reflect on what they have learned and take turns to write words associated with that topic on pieces of paper.
- These pieces of paper are then exchanged with another group.

Making Thinking Visible in Chemistry

7. Pictionary – Drawing and Sketching Ideas



- Members of the second group then take turns to represent their understanding of each word in the form of a diagram (make their thinking visible).
- Other members of the same group try to guess the word from the drawing.

Making Thinking Visible in Chemistry

8. Taboo – Making Ideas Distinct and Clear



- Taboo is a word game.
- The objective of the game is for a player to have her partner guess the word that is printed on her playing card (e.g. *acid*) by describing it (verbalise their understanding of the word).
- The player is not allowed to say the actual word, but must rely on their own understanding in order to best describe it.

Making Thinking Visible in Chemistry

9. Concept Cartoons



- Naylor & Keogh, 2000.

Making Thinking Visible in Chemistry

9. Concept Cartoons

- Concept cartoons show a group of students discussing a particular situation or phenomenon. The concept cartoon is used as a catalyst to initiate a discussion.
 - Each one of the students in the cartoon has a different point-of-view about the situation.
- Students in class interpret the situation and discuss why they agree or disagree with the proposed points-of-view.
- Students in class are also encouraged to propose and justify their own ideas about the situation or phenomenon.

Making Thinking Visible in Chemistry

9. Concept Cartoons

They do not necessarily have a single *right answer*. In many cases, the only reasonable conclusion is “*It depends on...*”. Even apparently simple situations usually turn out to have a number of possible complicating factors when they are examined closely. *It is helpful for students to realise that scientific problems may not have a single correct answer*. This helps to reinforce a view of science as tentative, in which beliefs are justified by the evidence available, but can be modified if additional evidence emerges.

Making Thinking Visible in Chemistry

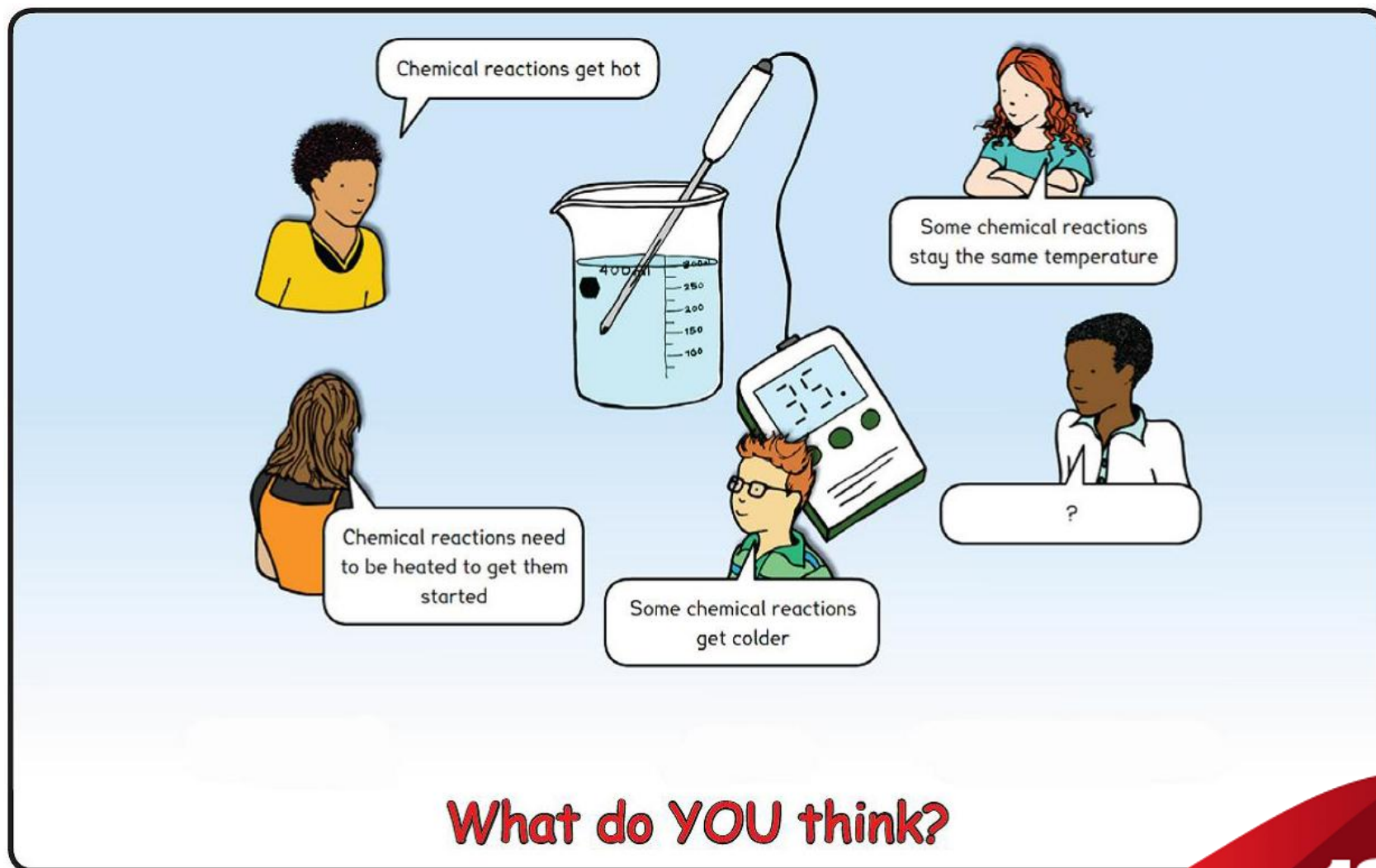
9. Concept Cartoons

How are Concept Cartoons Used?

- Making students' ideas explicit.
- Challenging and developing students' ideas.
 - Illustrating alternative view points.
 - Providing a stimulus for discussion.
- Helping students to ask their own questions.
 - Providing starting points for investigations.
- Promoting involvement and enhancing motivation.
- Applying scientific ideas in everyday situations.

Making Thinking Visible in Chemistry

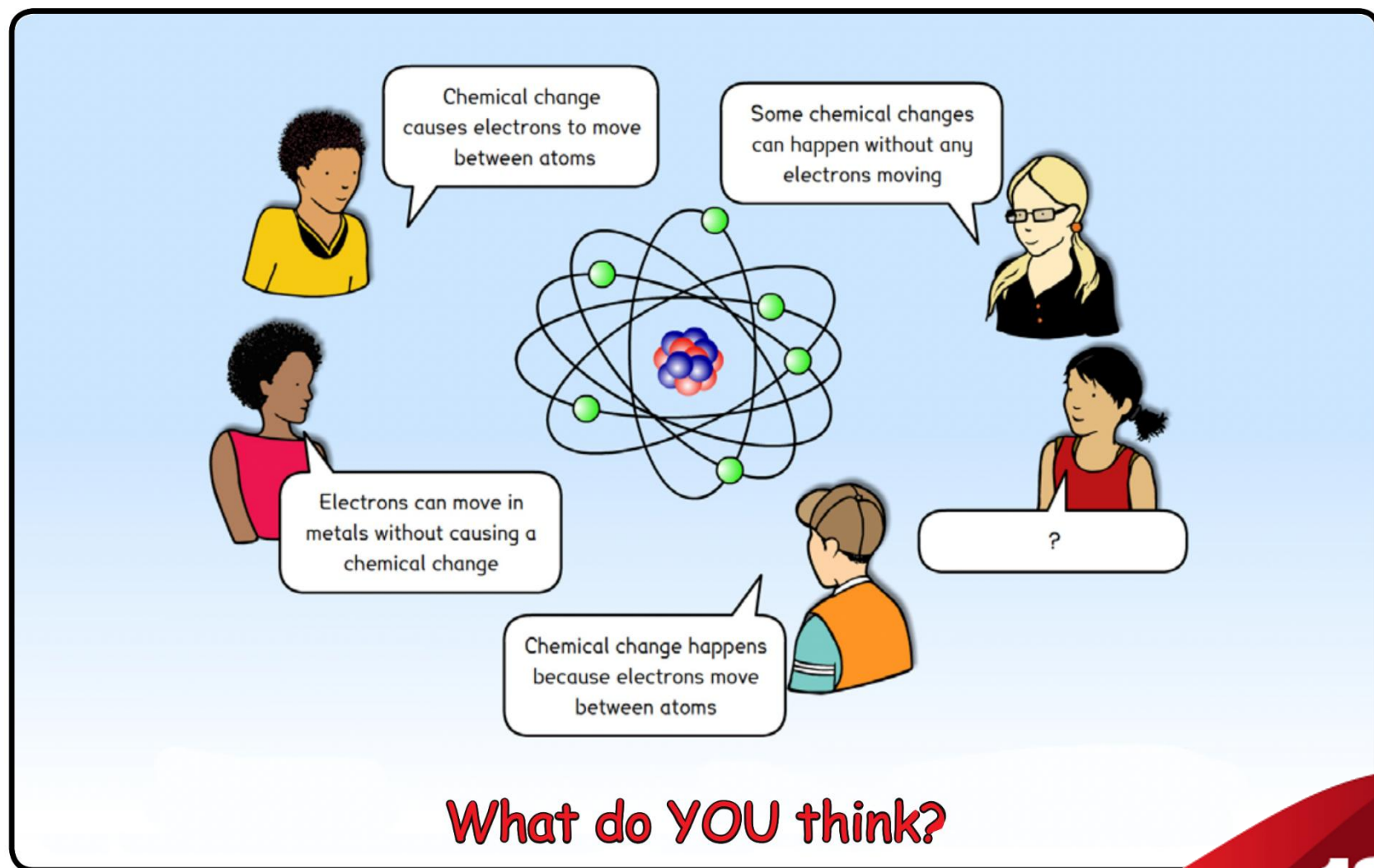
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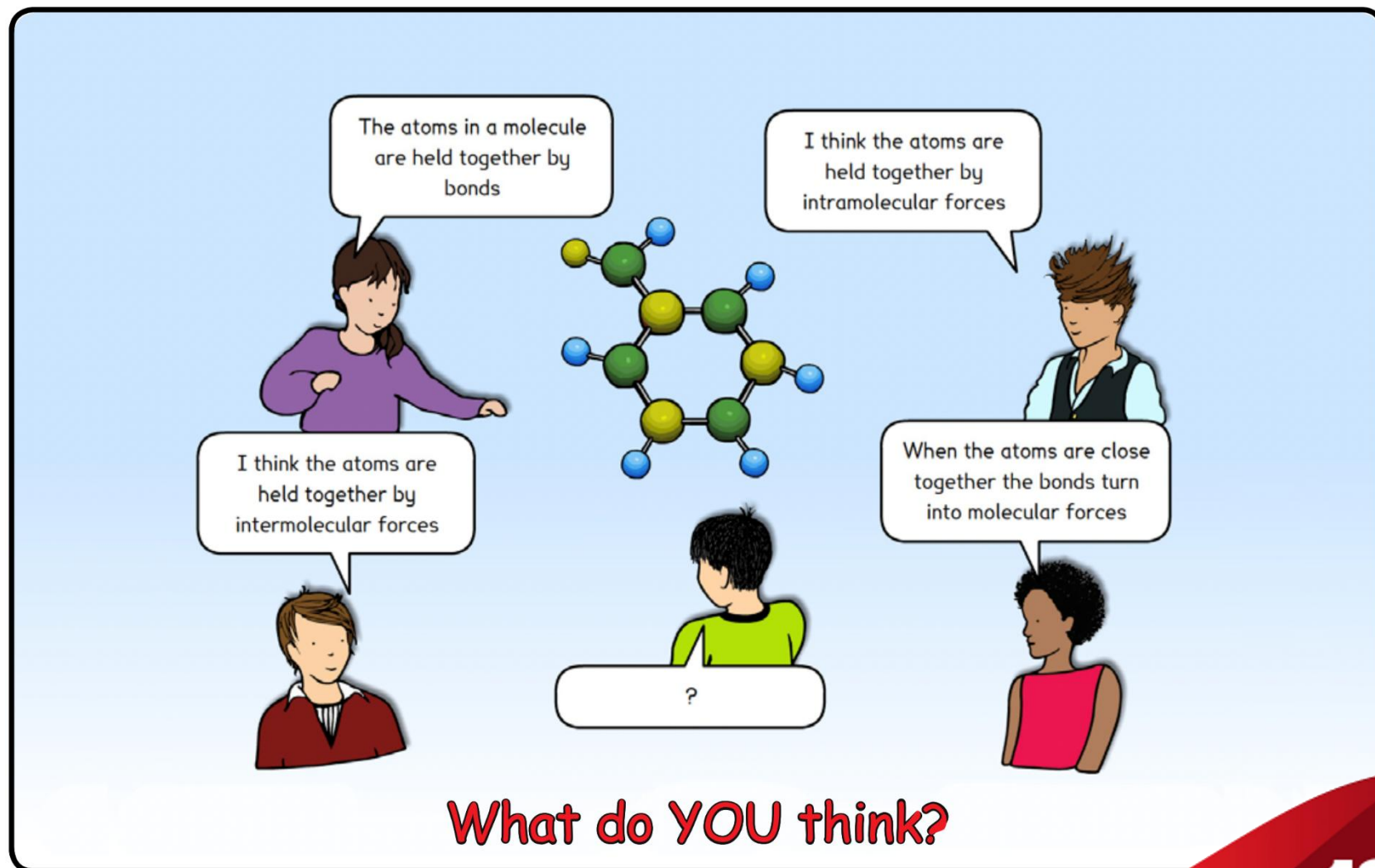
9. Concept Cartoons



- Naylor & Keogh, 2000.

Making Thinking Visible in Chemistry

9. Concept Cartoons



- Naylor & Keogh, 2000.

Making Thinking Visible in Chemistry

10. My Favourite Mistake



Home

Making Thinking Visible in Chemistry

10. My Favourite Mistake

- Students are given a question that can be briefly answered on a small piece of paper, e.g. Post-it-Note.
 - Examples of questions that could be used for Chemistry include; balancing chemical equations, drawing dot-and-cross diagrams, drawing isomers, and simple mole calculations.
- The teacher collects the students' answers and looks through them to choose her *favourite mistake*. This could be a novel mistake or a common misconception.
- As the teacher selects her favourite mistake, the students should be engaged in another task.

Making Thinking Visible in Chemistry

10. My Favourite Mistake

- The teacher writes her favourite mistake on the board, or re-writes it on a piece of paper to show through a visualiser. This is to protect the identity of the student who may be recognised from their handwriting!
- Students are then asked to comment on the answer that is being shared with them. In general, students are quite forthcoming when criticising the work of other students!
- Firstly, the teacher asks the class of students what is *good* about the answer, e.g. all of the formulae are correct.
 - Secondly, the teacher guides her students in identifying mistakes and misconceptions.

Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations

- Students are given a concept in Chemistry, e.g. *diffusion*. Students then have to:
 - **S**tate the definition of the concept.
 - **E**laborate on the definition, “In other words...”
 - Give an e**X**ample of the concept.
 - Give an abstract **I**llustration of the concept (analogy). For example, “Diffusion is like a game of chess. The pieces (molecules) start at opposite ends of the board in a high concentration, but are mixed together (homogeneous) due to (random) movement by the end of the game.

Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

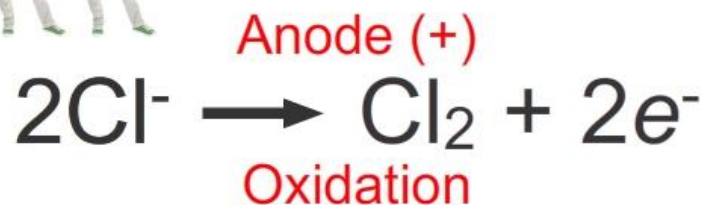
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Making Thinking Visible in Chemistry

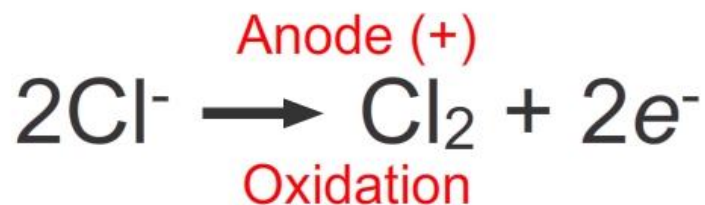
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Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



electrons move
through wires

- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



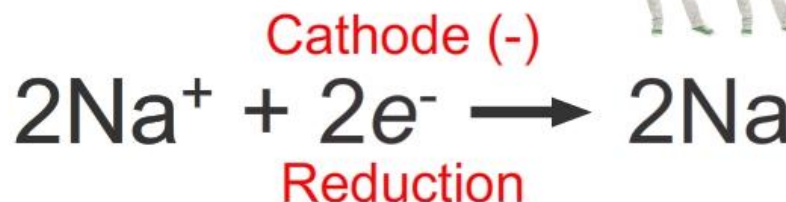
2Na^+



- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

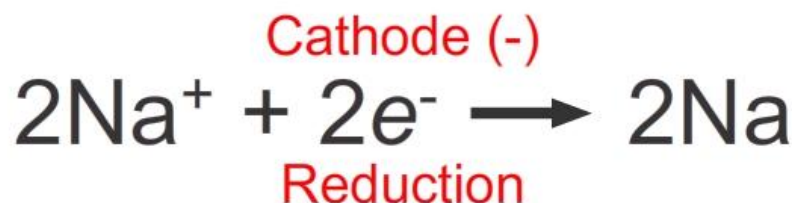
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Making Thinking Visible in Chemistry

11. SEXI – Analogies and Abstract Illustrations



- Public transport analogy for electrolysis.

Making Thinking Visible in Chemistry

12. Predict – Observe – Explain

- Students *predict* what will happen when a hard boiled egg is placed on top of a glass milk bottle that contains a piece of burning tissue paper.



Making Thinking Visible in Chemistry

12. Predict – Observe – Explain



- Students *predict* what will happen when a hard boiled egg is placed on top of a glass milk bottle that contains a piece of burning tissue paper.
- Students *observe* what happens when the experiment is allowed to run its course.

Making Thinking Visible in Chemistry

12. Predict – Observe – Explain



- Students *predict* what will happen when a hard boiled egg is placed on top of a glass milk bottle that contains a piece of burning tissue paper.
- Students *observe* what happens when the experiment is allowed to run its course.
- Students *explain* the scientific principles behind what has been observed.

Making Thinking Visible in Chemistry

12. Predict – Observe – Explain



- Students reflect individually about what they have observed, and its scientific explanation.
- Students discuss in small groups and try to arrive at an explanation for the phenomenon.
- Students present their solutions to their peers, who offer constructive criticism where appropriate.

Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies



Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies

- Cooperative learning strategies provide a framework for students to interact with each other.
- Cooperative learning strategies actively engage all of the students at the same time.
- One underlying assumption is that some students are more willing to discuss their ideas with their peers, and less likely to discuss their ideas with their teachers in front of the whole class.

Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies

- The following example is a cooperative learning strategy that encourages students to work in pairs while revising the reactions of acids.
- Half of the students in the class are given cards with the name of an acid printed on them.
- The other half of the class are given cards with the names of metals, bases and carbonates printed on them.

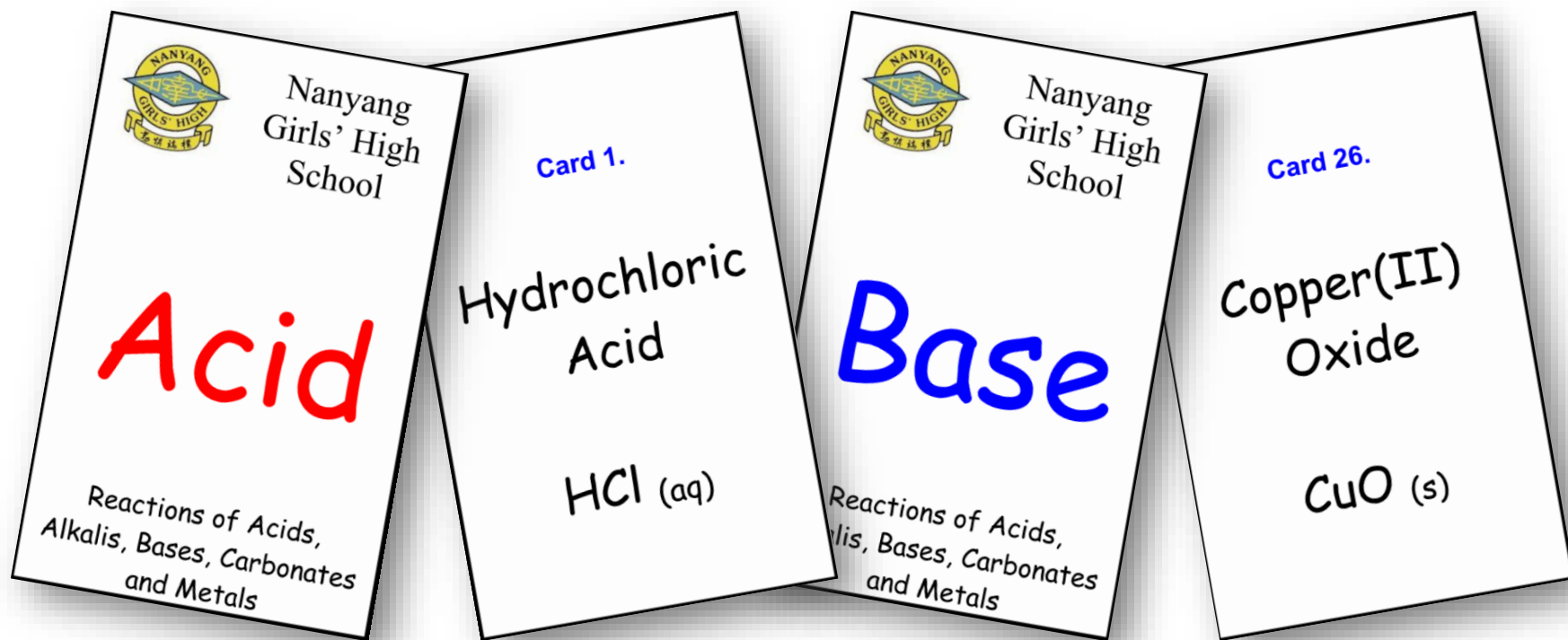
Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies

- Students walk around the classroom holding their cards up so that the reagents printed on them are clearly visible.
 - When an acid meets a metal, base or carbonate – they *react*.
- The two students write the balance chemical equation for their reaction. Students are encouraged to write their equations on the whiteboard or mahjong paper.
 - Students swap cards and look for another partner to react with.

Making Thinking Visible in Chemistry

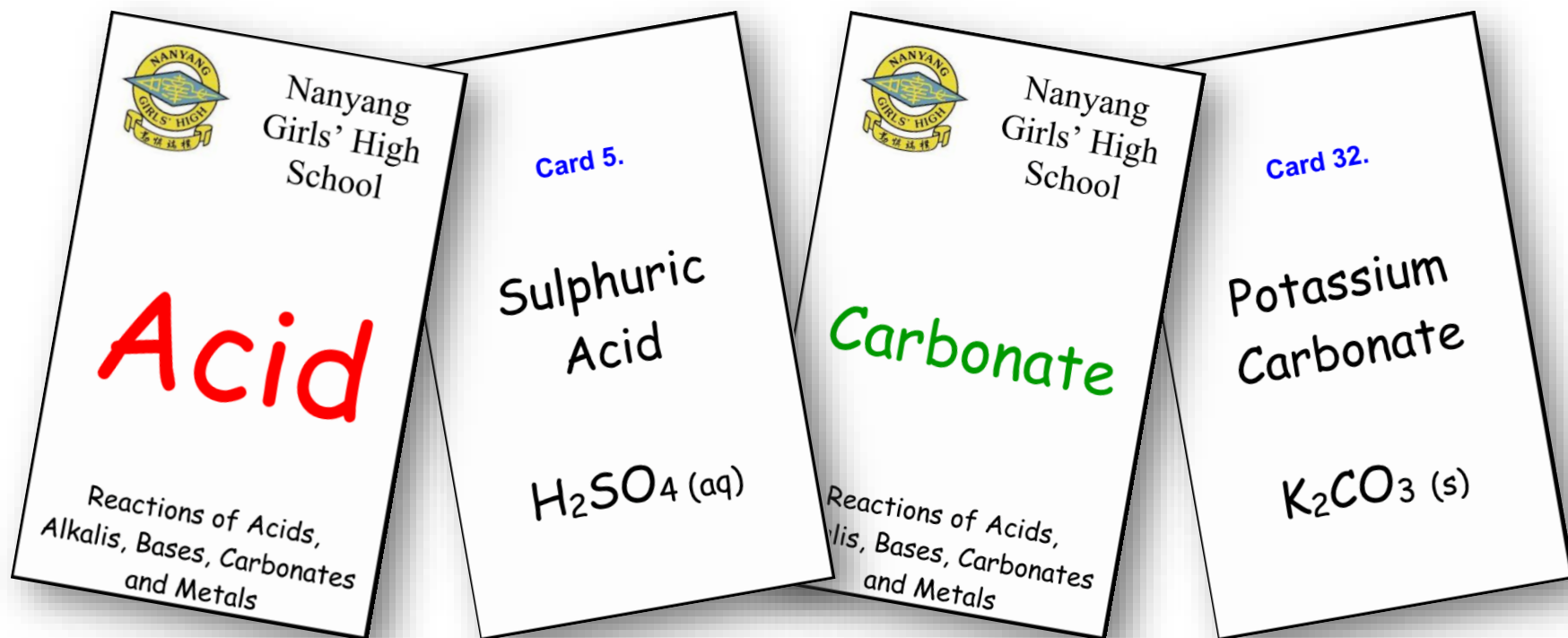
13. Cooperative Learning Strategies



- Students think as they discuss their ideas with each other. Students give each other constructive criticism.

Making Thinking Visible in Chemistry

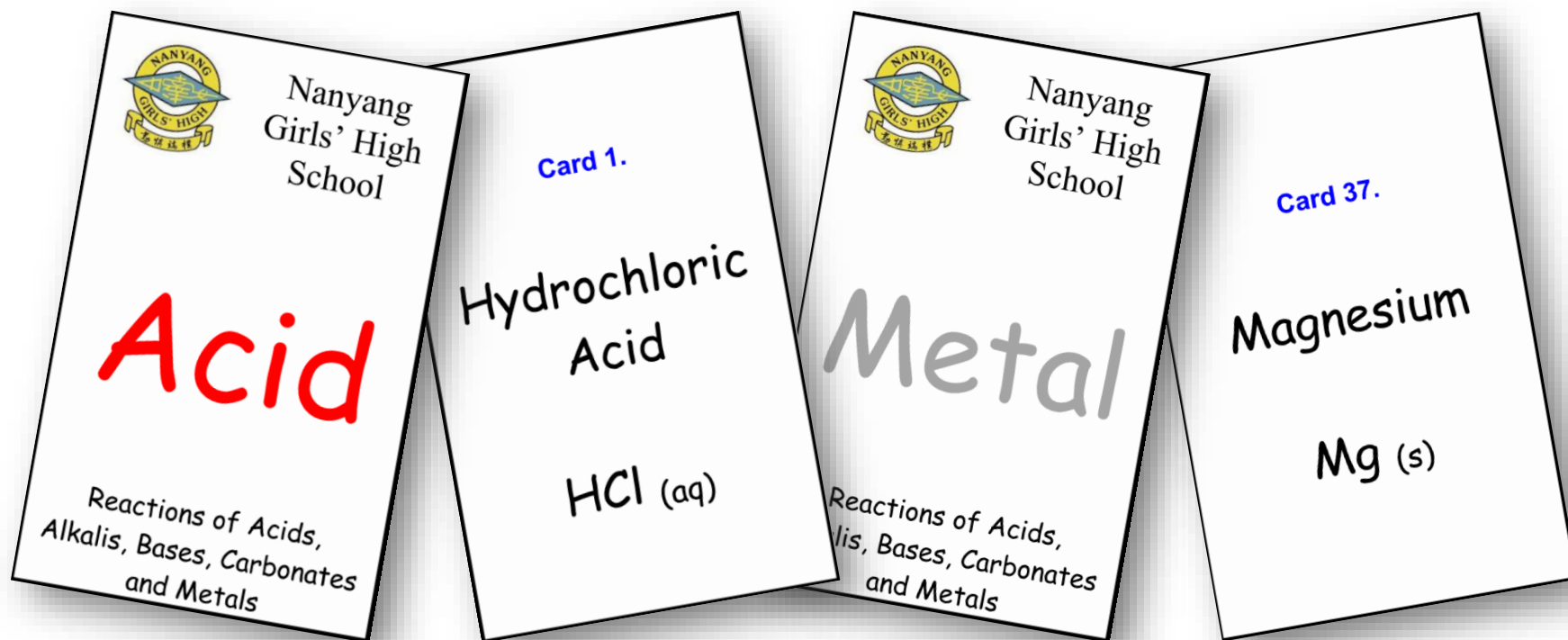
13. Cooperative Learning Strategies



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Making Thinking Visible in Chemistry

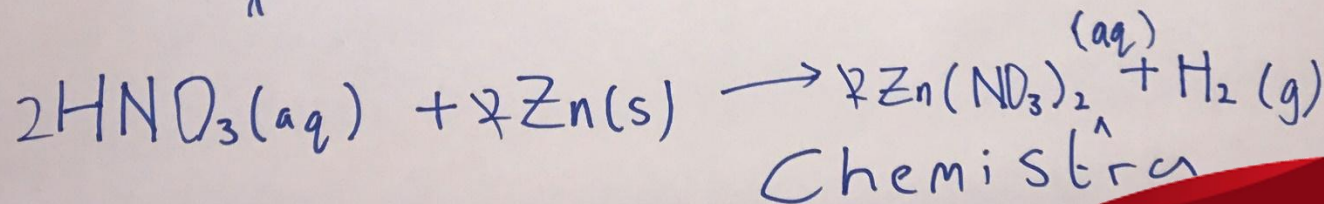
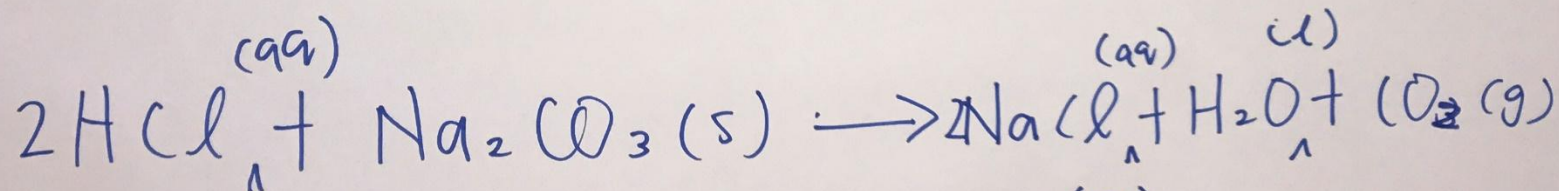
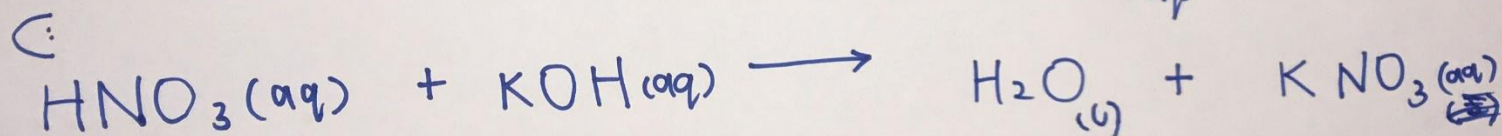
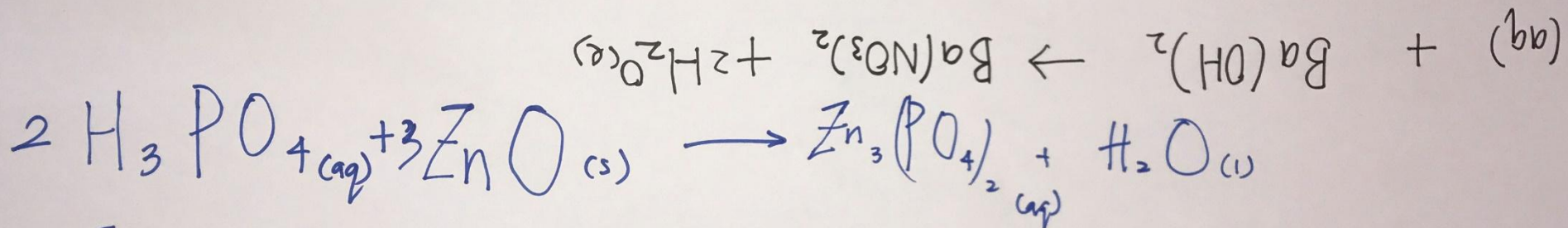
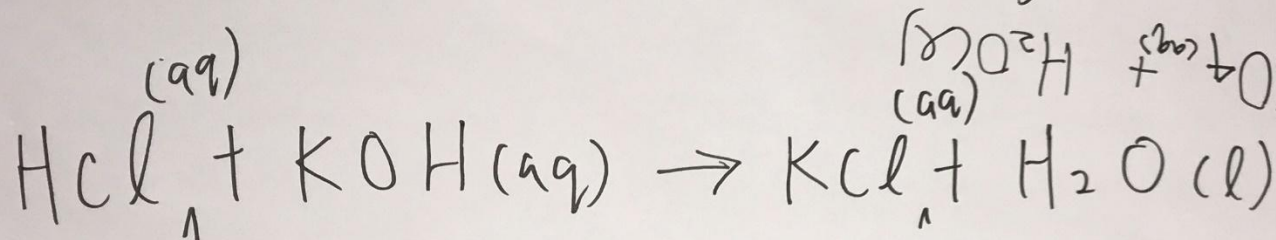
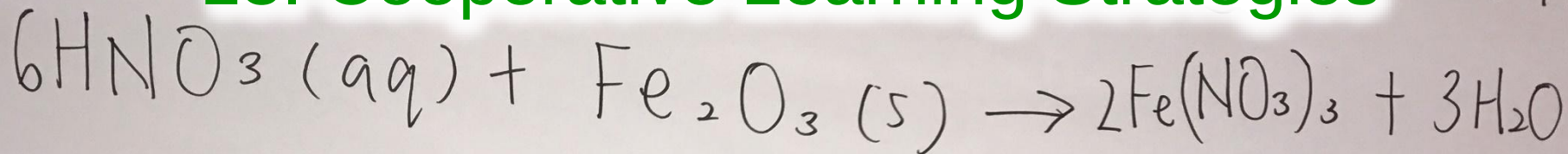
13. Cooperative Learning Strategies



- Students think as they discuss their ideas with each other. Students give each other constructive criticism.

Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies



Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies

- This part of the activity is similar to a Harvard Project Zero Thinking Routine called “ *Chalk Talk* ”.
 - Students write down their ideas, or in this case, balanced chemical equations, on a large piece(s) of paper that is shared by the entire class. Students use markers with black or blue ink for this part of the activity.
 - Once students have finished writing their balanced chemical equations, they review and critique the work of the other students – writing *helpful comments*, *suggestions* and *corrections*. Students use markers with red or green ink for this part of the activity.

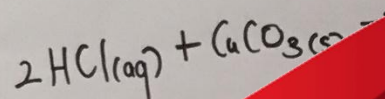
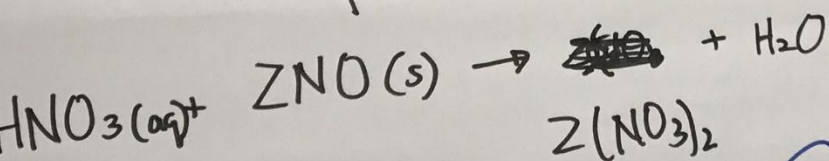
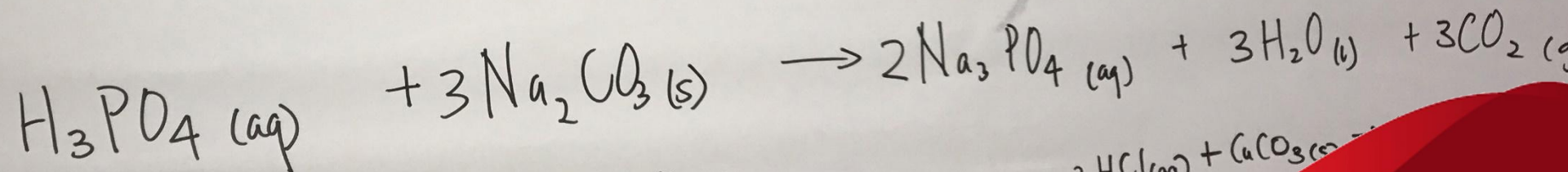
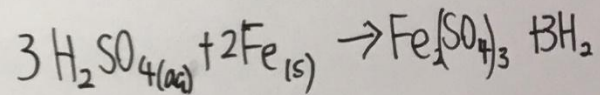
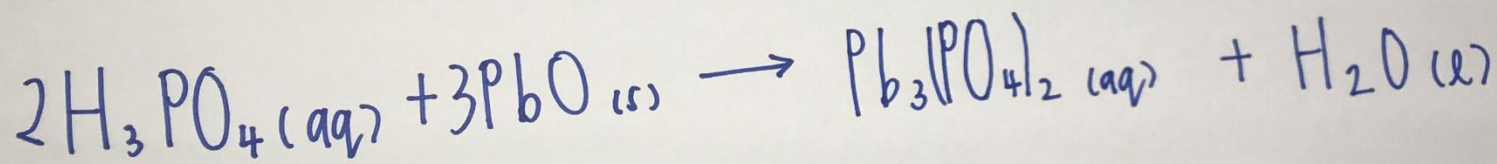
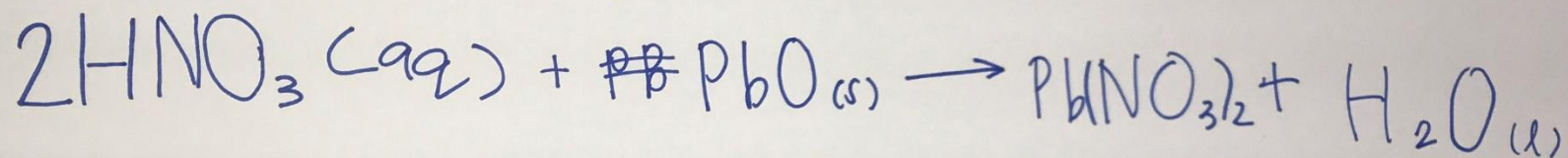
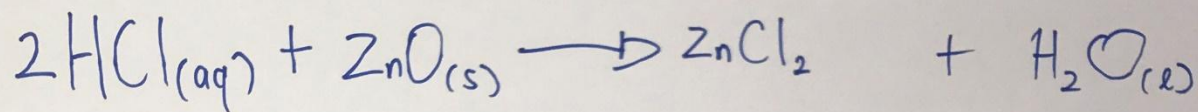
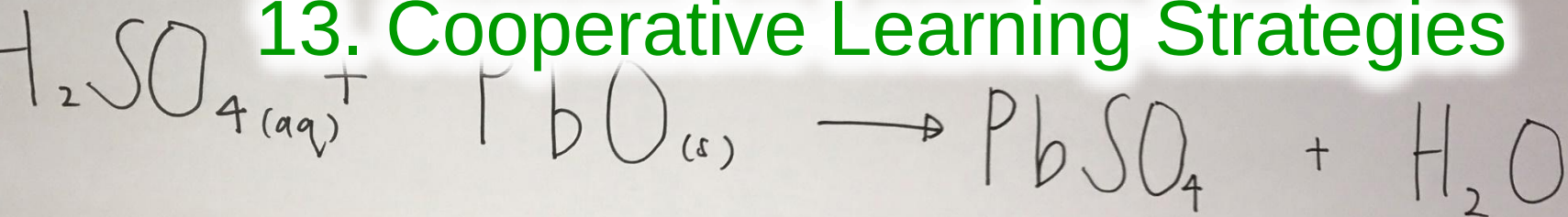
Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies

- What errors or misconceptions can you see in these pieces of work?

Making Thinking Visible in Chemistry

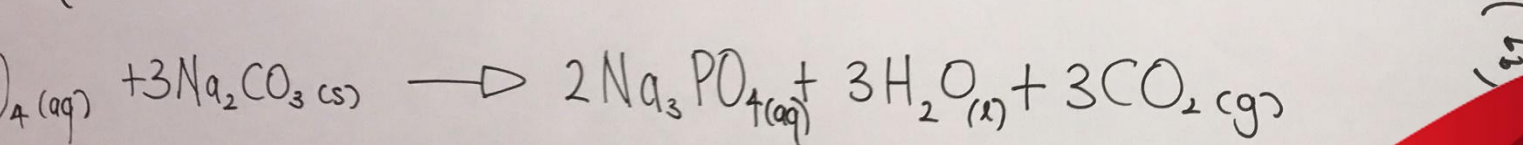
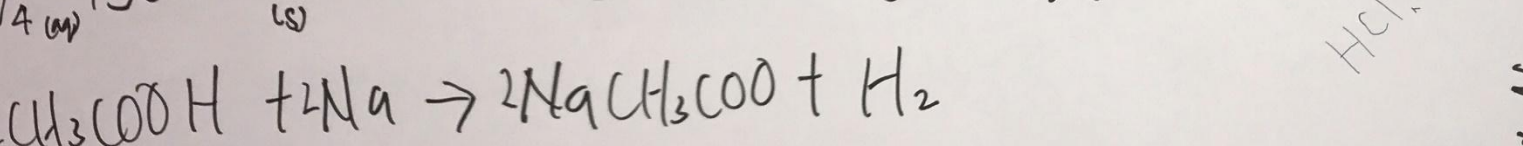
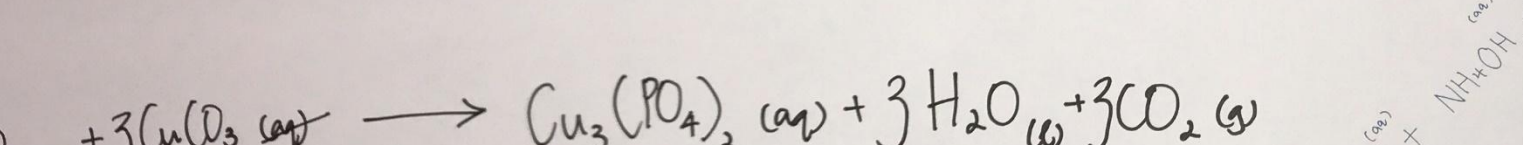
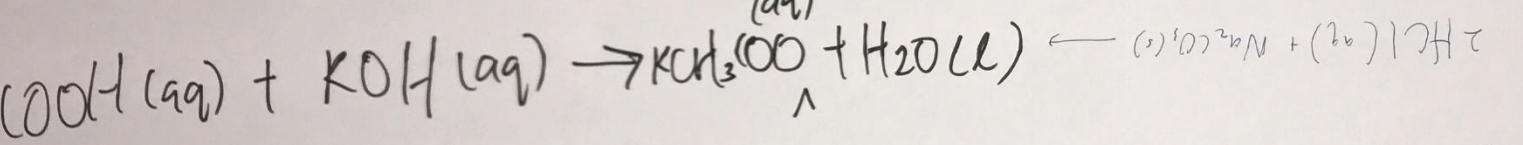
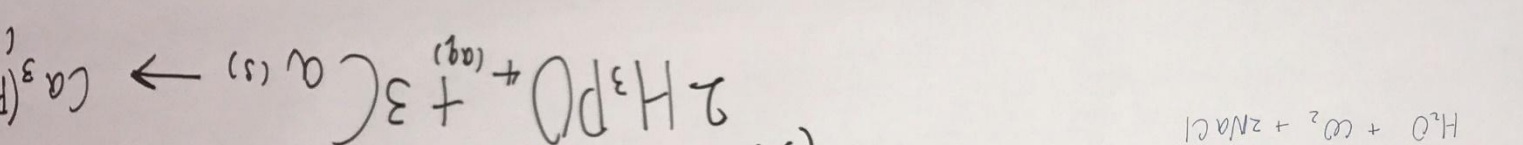
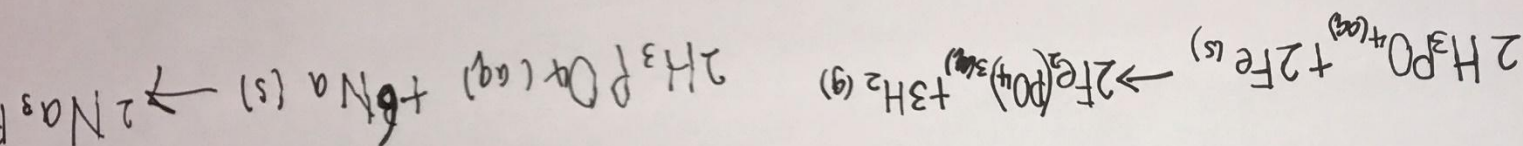
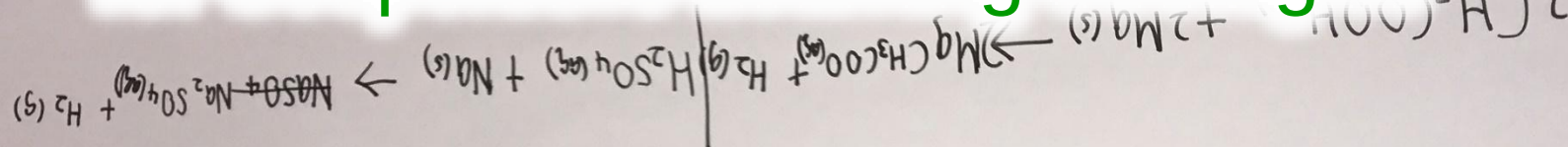
13. Cooperative Learning Strategies



Chemistry

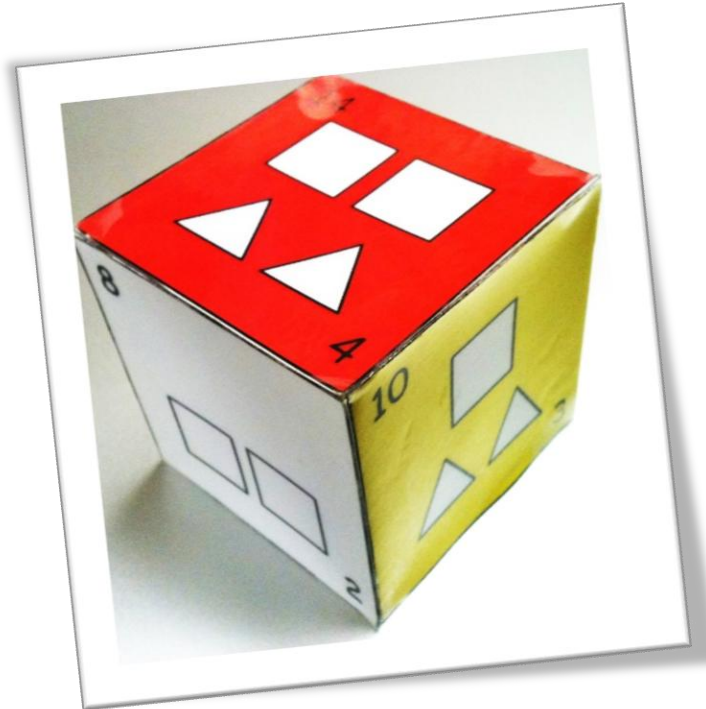
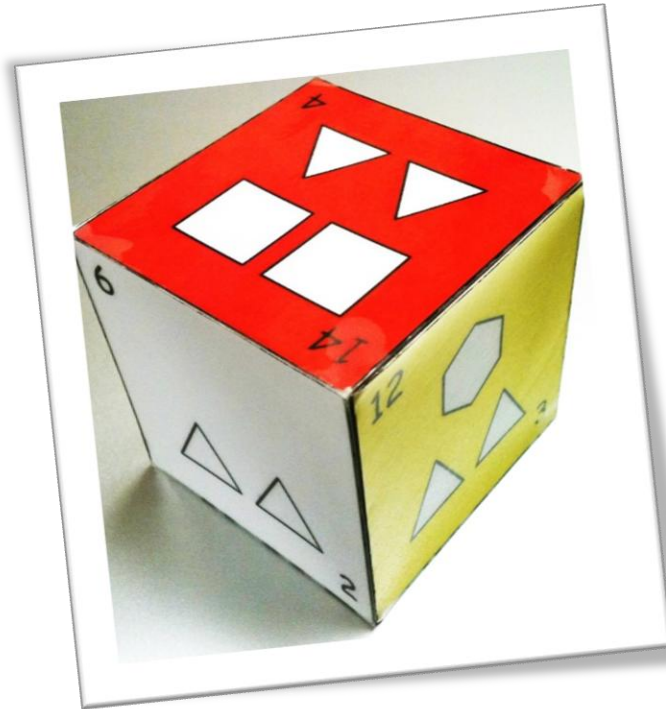
Making Thinking Visible in Chemistry

13. Cooperative Learning Strategies



Making Thinking Visible in Chemistry

14. Curiosity Cubes and Thinking Tubes



- Based upon what can be observed, students try to deduce what pattern is printed on the bottom of the cube.
- Students think out loud as they reason with their peers.
 - The activity can be used as an introduction to atomic structure.

Making Thinking Visible in Chemistry

14. Curiosity Cubes and Thinking Tubes



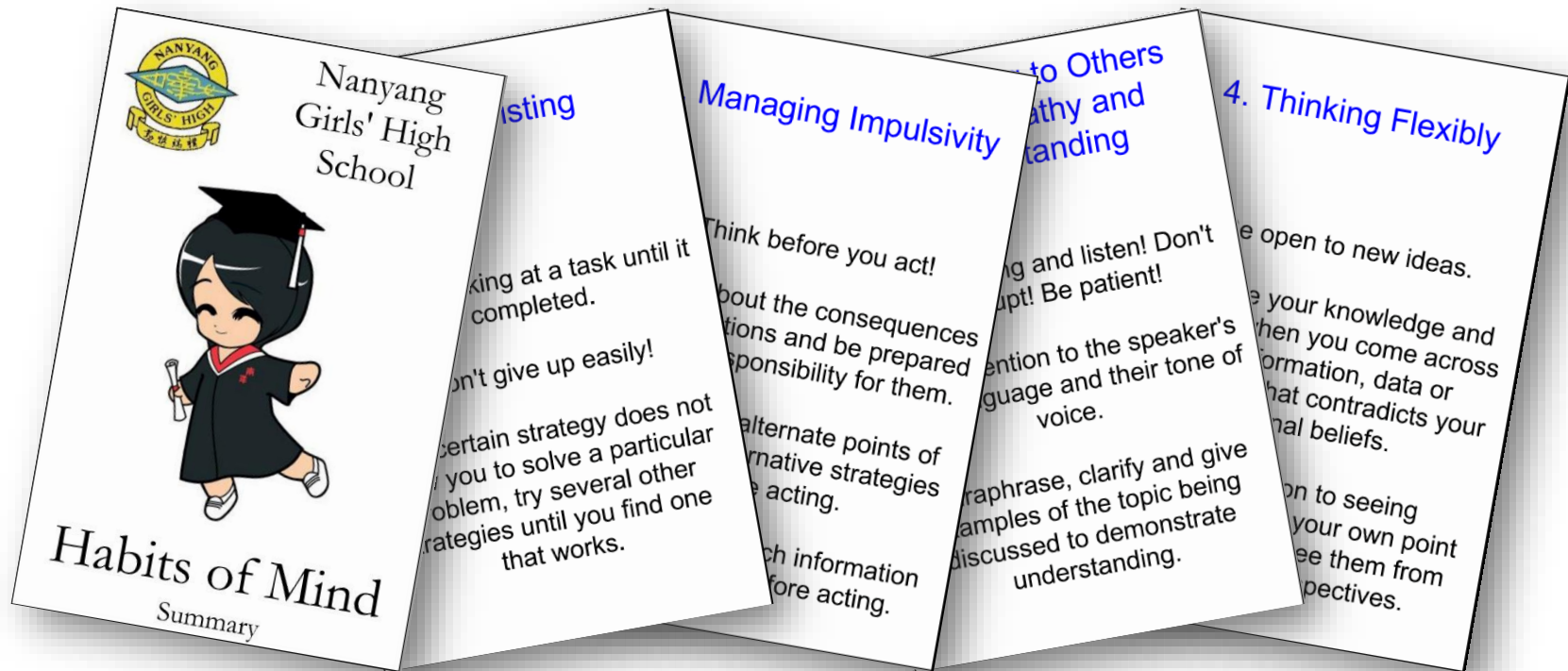
Making Thinking Visible in Chemistry

14. Curiosity Cubes and Thinking Tubes

- Each cardboard tube has four holes, through which a piece (or pieces) of string has been threaded.
- Students gently pull the pieces of string and observe what happens.
 - Students discuss their observations and suggest possible relationships between the variables.
- In doing so, students draw conclusions about what cannot be observed directly.
- The activity challenges the students to think critically.
- The activity can be used as an introduction to atomic structure.

Making Thinking Visible in Chemistry

15. Habits of Mind



Making Thinking Visible in Chemistry

15. Habits of Mind

1. Persisting
2. Thinking and Communicating with Clarity and Precision
3. Managing Impulsivity
4. Gathering Data Through All Senses
5. Listening with Empathy and Understanding
6. Creating, Imagining and Innovating
7. Thinking Flexibly
8. Responding with Wonderment and Awe

Making Thinking Visible in Chemistry

15. Habits of Mind

9. Thinking About Thinking (Metacognition)

10. Taking Responsible Risks

11. Striving for Accuracy and Precision

12. Finding Humour

13. Questioning and Posing Problems

14. Thinking Interdependently

15. Applying Past Knowledge to New Situations

16. Remaining Open to Continuous Learning

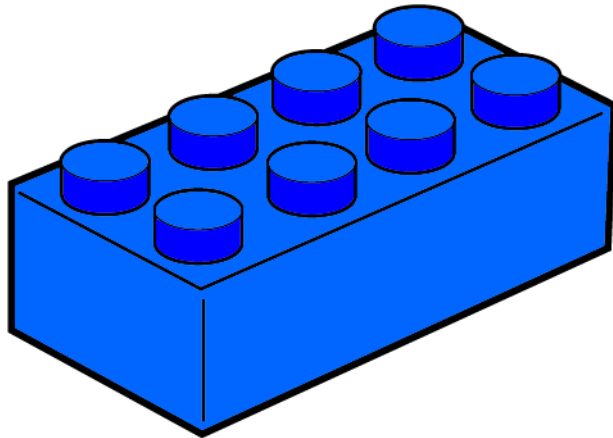
Making Thinking Visible in Chemistry

15. Habits of Mind

- The sixteen *Habits of Mind* inform students how to behave intelligently when they are faced with a novel problem that they do not know the immediate answer to.
- The Habits of Mind guide the students how to think in order to solve a complex problem.
- At the end of the problem solving process, students may reflect upon which of the sixteen Habits of Mind they relied upon the most.
- Students can be given brief biographies of famous Scientists and asked to suggest which Habits of Mind the Scientist exemplified the most.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

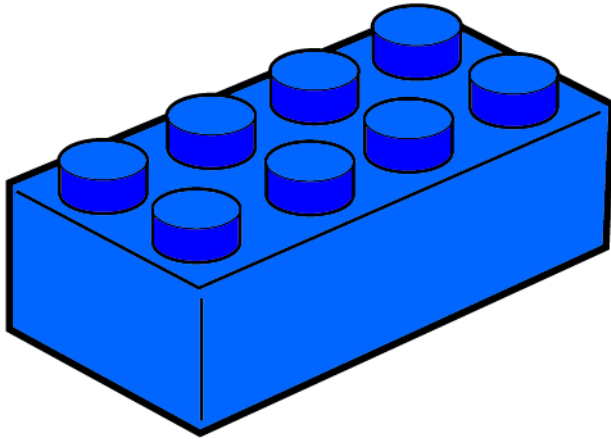


- An atom.

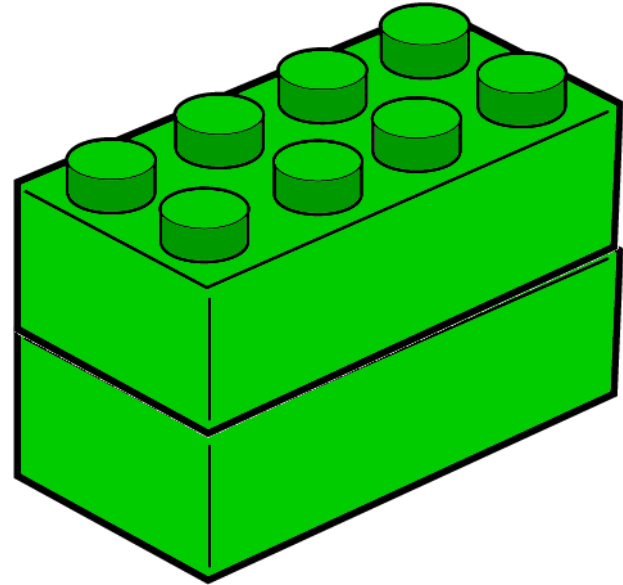
- Students can make their thinking and understanding of various concepts visible by using molecular modelling kits, e.g. Molymod®.
- An suitable alternative is to use LEGO® bricks to represent atoms. Although the detail of the model may be limited, LEGO® is relatively inexpensive and easy to use.

Making Thinking Visible in Chemistry

16. Using Lego® to Represent Particles



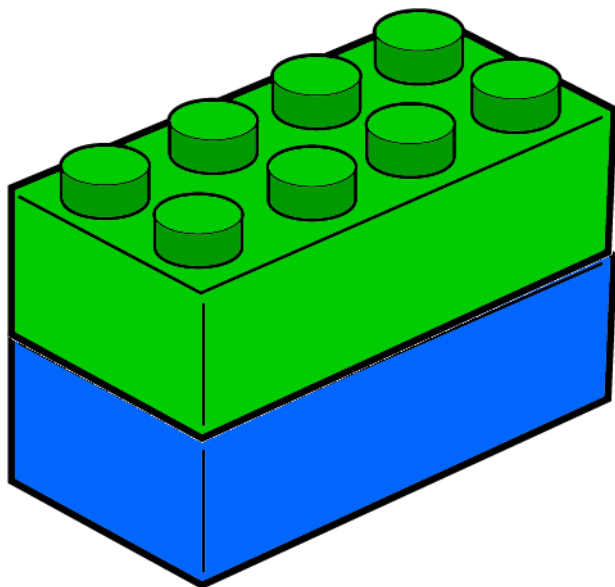
- An atom.



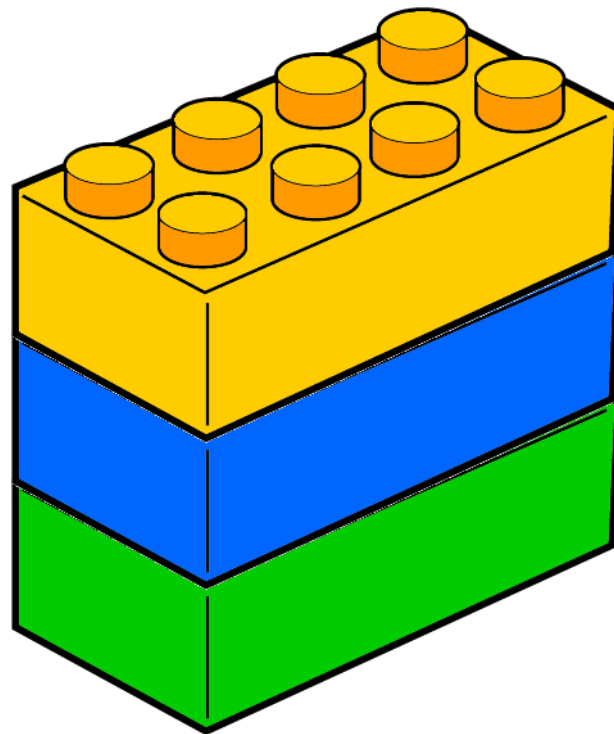
- An element.

Making Thinking Visible in Chemistry

16. Using Lego® to Represent Particles



- Compound #1.



- Compound #2.

- A mixture of two compounds.

Making Thinking Visible in Chemistry

16. Using Lego® to Represent Particles

- Using LEGO® to visualise the arrangement of particles in solid, liquid and gaseous states.
- What are the limitations of this model?

Making Thinking Visible in Chemistry

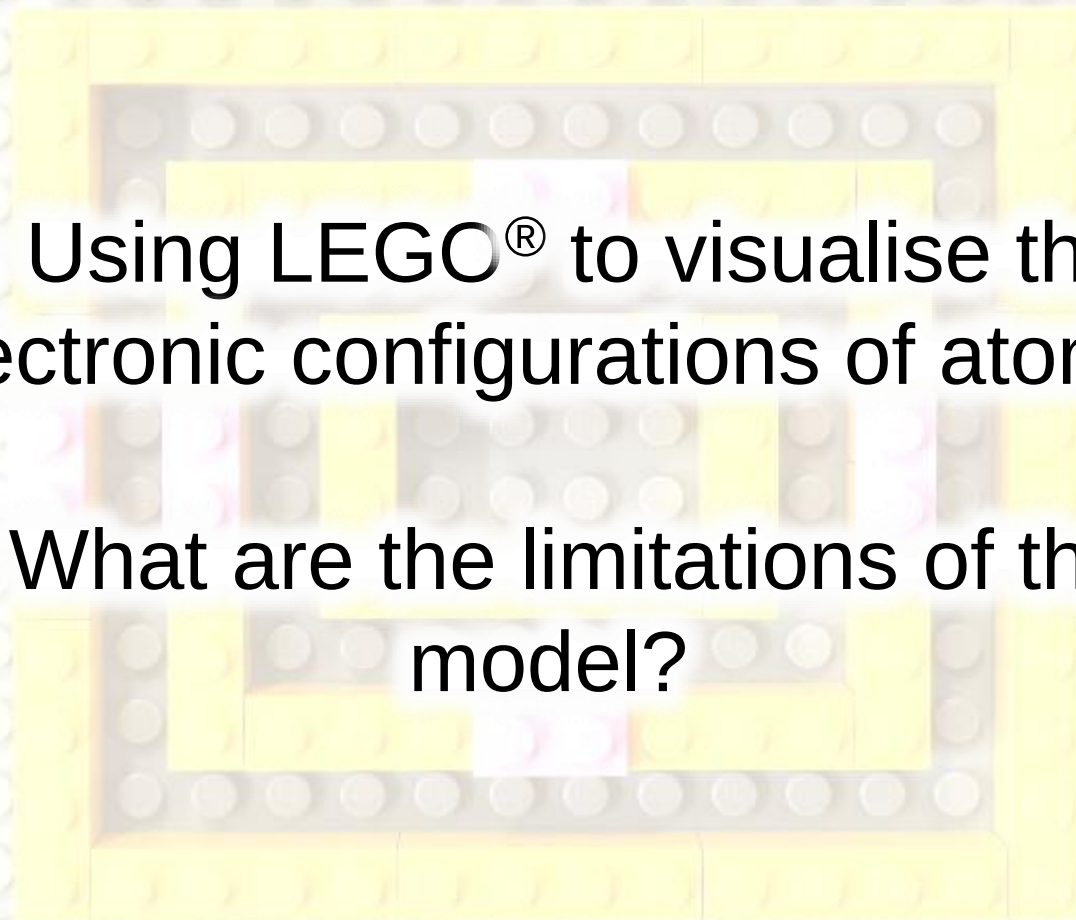
16. Using Lego® to Represent Particles



Making Thinking Visible in Chemistry

16. Using Lego® to Represent Particles

- Using LEGO® to visualise the electronic configurations of atoms.
- What are the limitations of this model?



Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

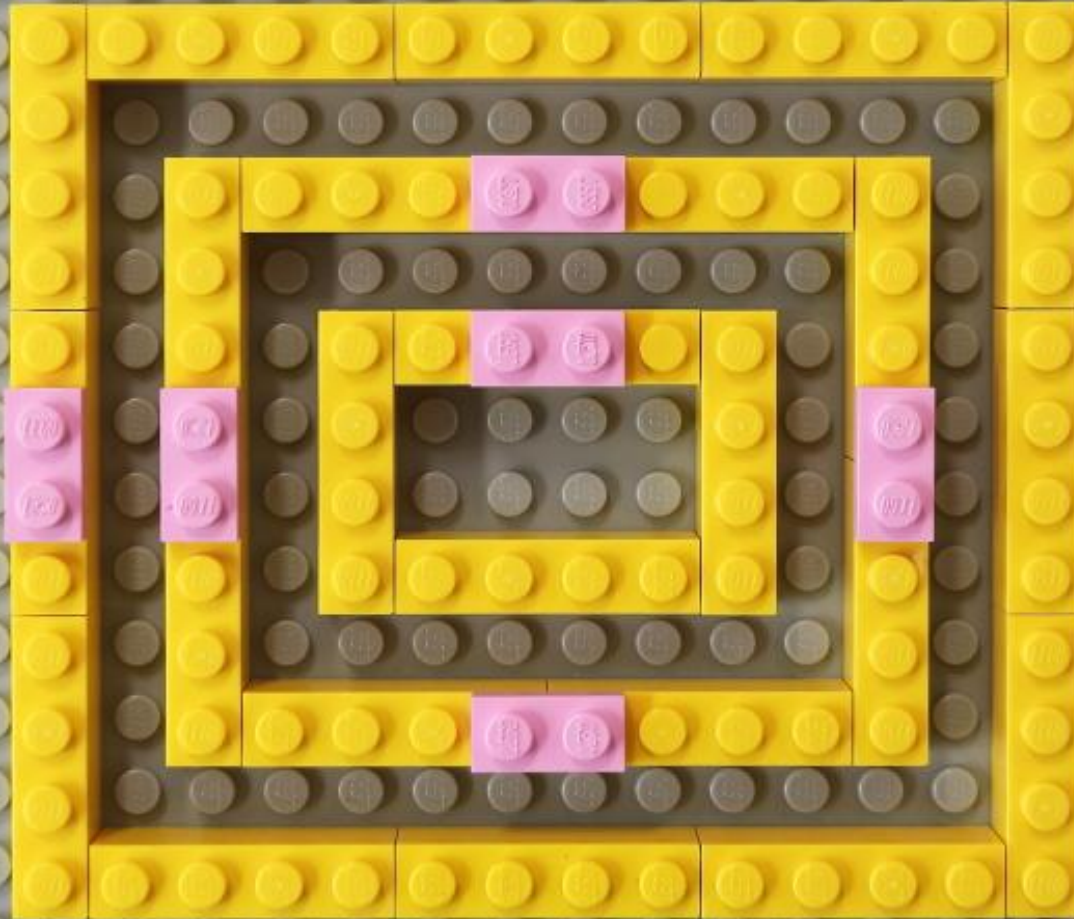


Photo credits: Mr. Chris Talbot and Mr. Jack Tan,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- Using LEGO® to visualise optical isomers.
- What are the limitations of this model?

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles



Photo credits: Mr. Chris Talbot and Mr. Jack Tan,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- Using LEGO® to visualise the arrangement of particles in a mixture of iron and sulfur, contrasted with their arrangement in the compound iron(II) sulfide.
- What are the limitations of this model?

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

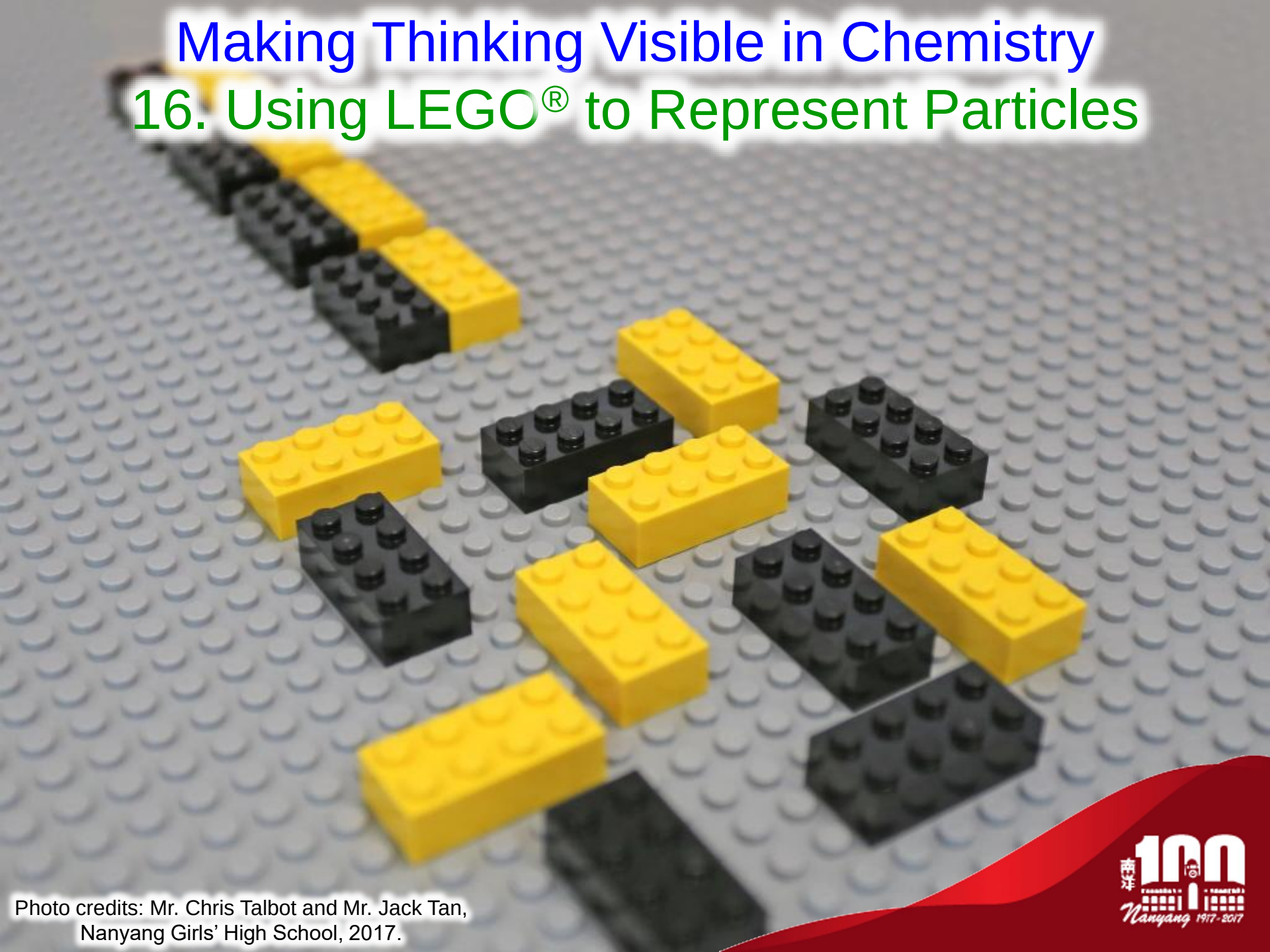
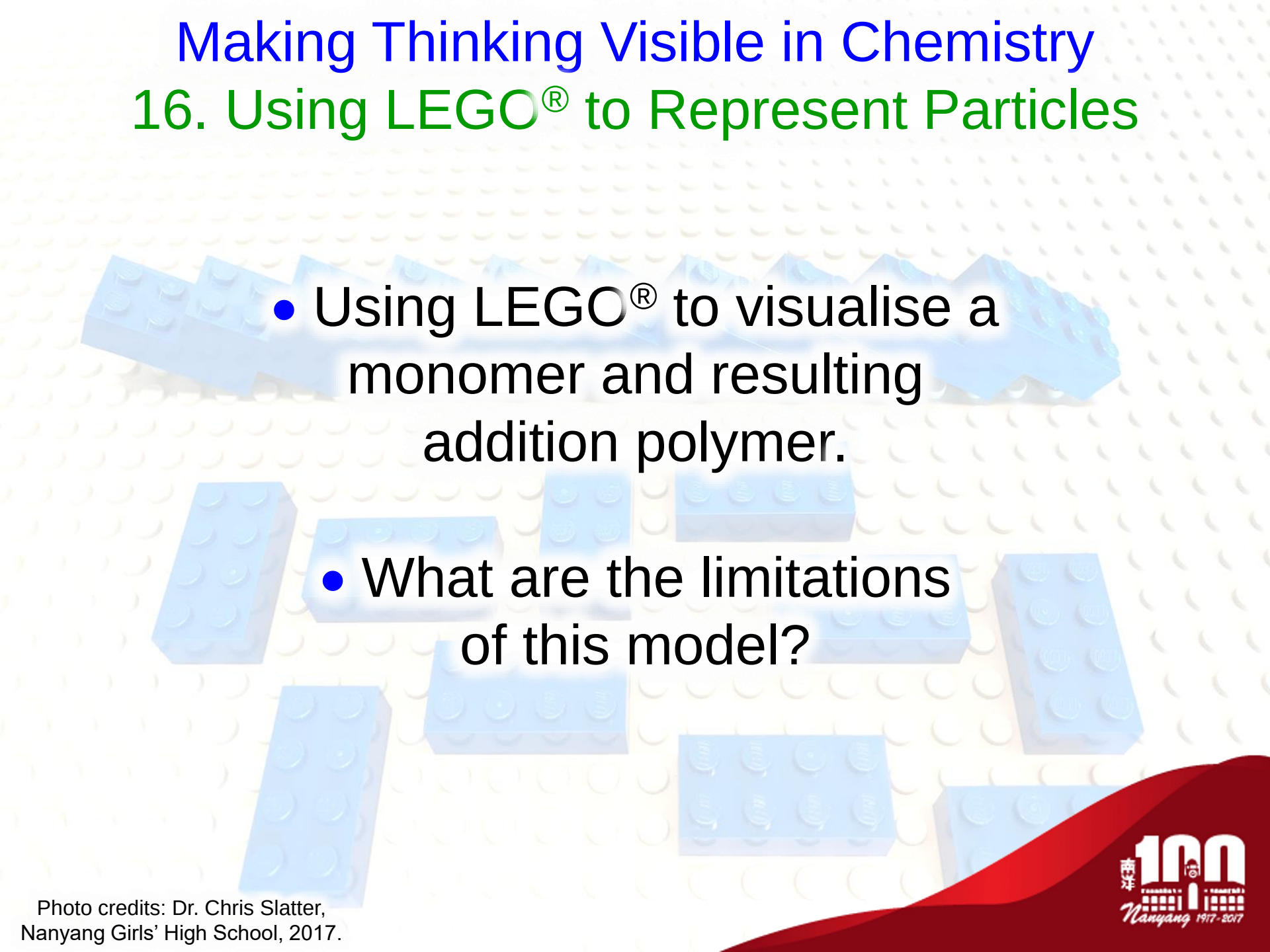


Photo credits: Mr. Chris Talbot and Mr. Jack Tan,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- 
- Using LEGO® to visualise a monomer and resulting addition polymer.
 - What are the limitations of this model?

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

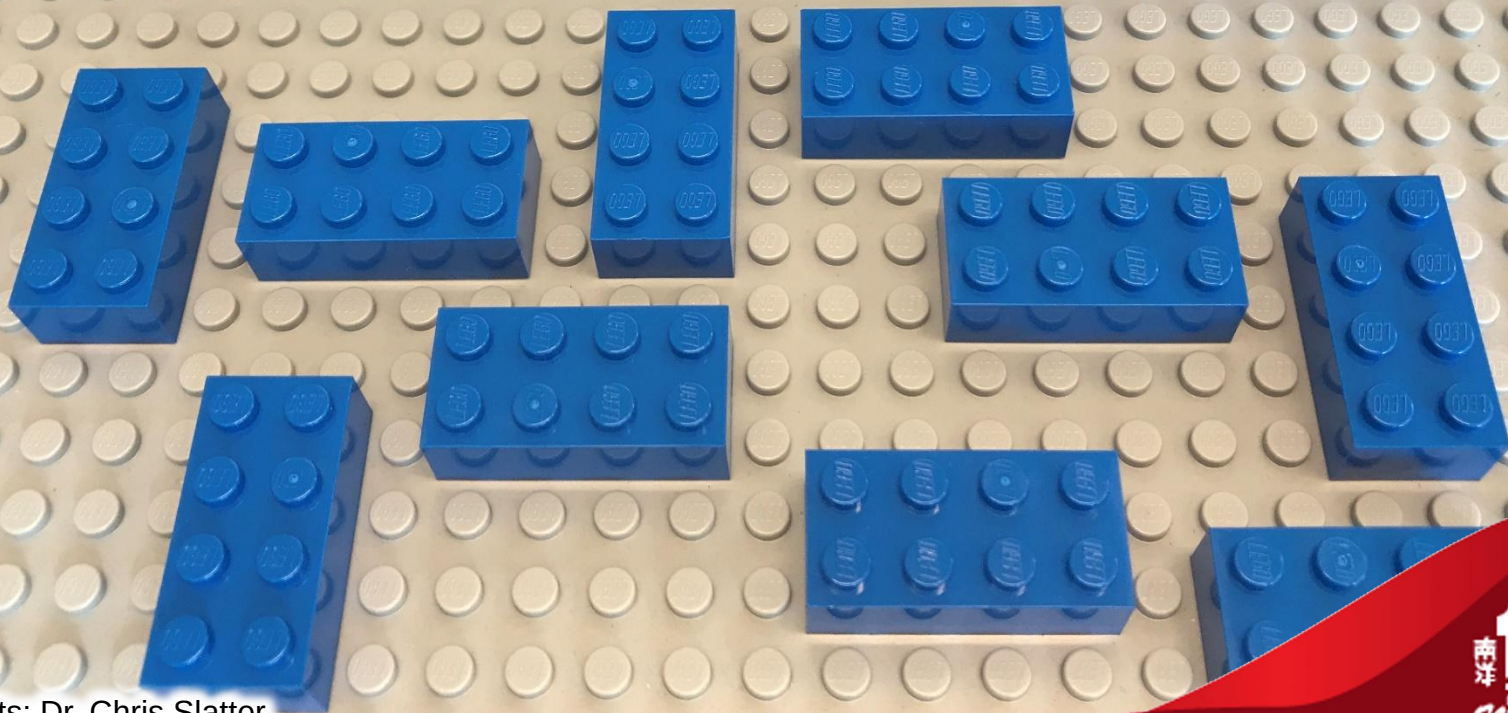
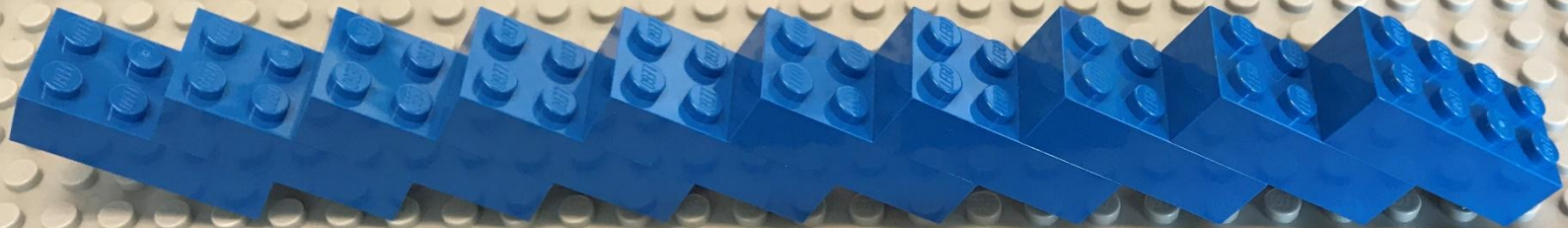


Photo credits: Dr. Chris Slatter,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- Using LEGO® to visualise the arrangement of ions in an ionic solid *e.g.* sodium chloride.
- What are the limitations of this model?

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

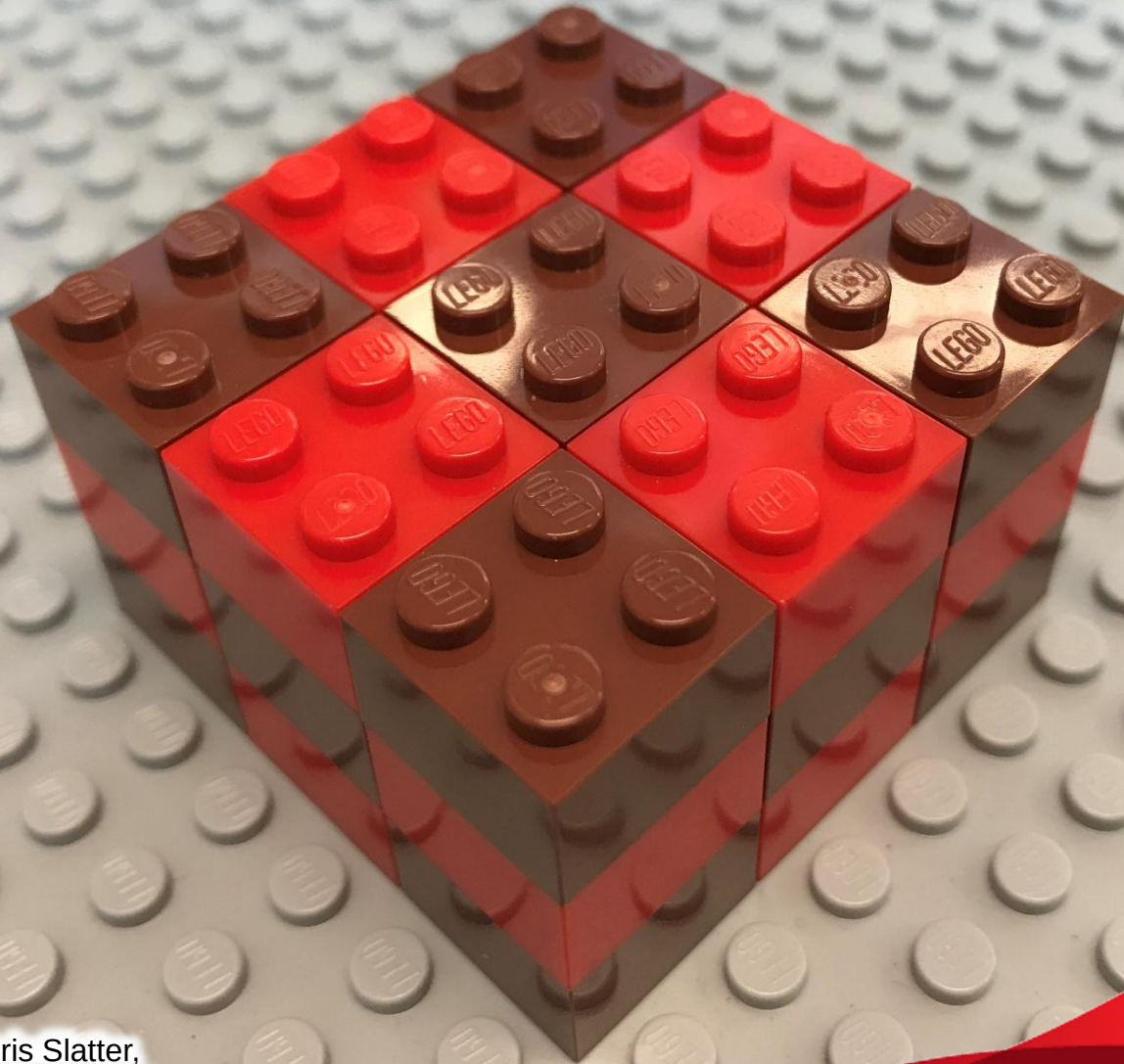


Photo credits: Dr. Chris Slatter,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- Using LEGO® to visualise the number of electrons in the valence shell of an atom, illustrating Periodic Trends.
- What are the limitations of this model?

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

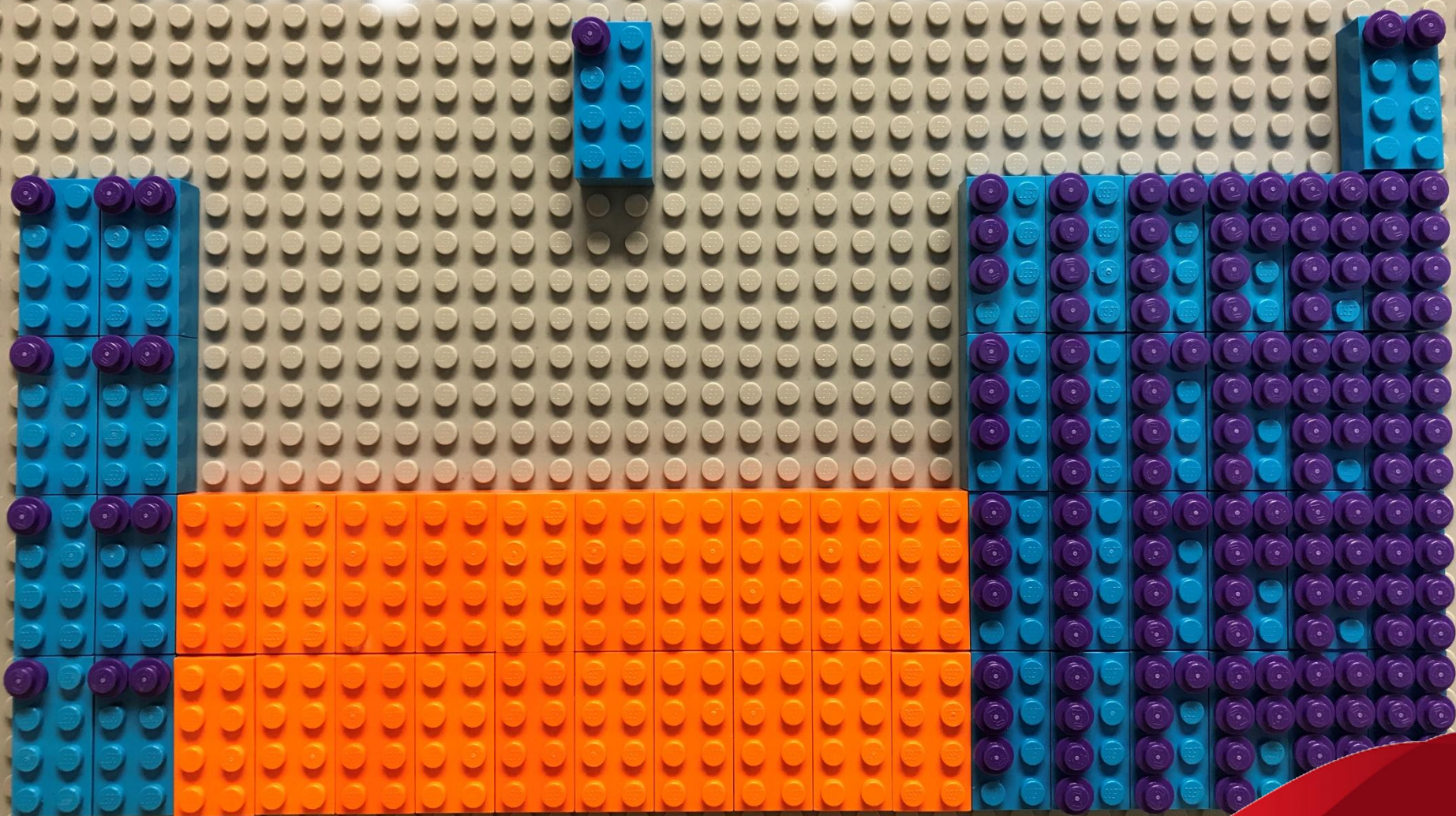
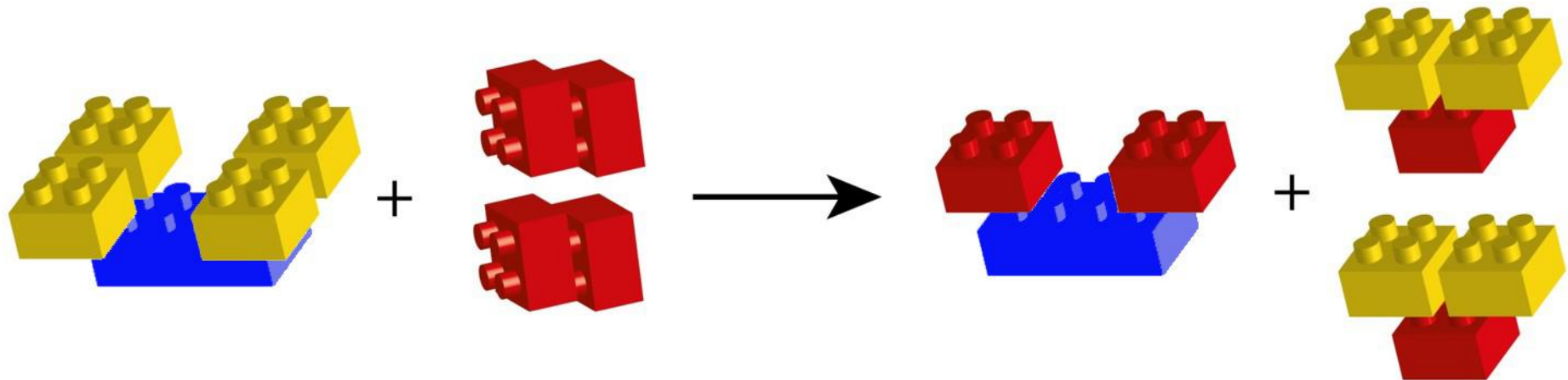


Photo credits: Mr. Chris Talbot and Mr. Jack Tan,
Nanyang Girls' High School, 2017.

Making Thinking Visible in Chemistry

16. Using LEGO® to Represent Particles

- LEGO® can also be used to represent balanced chemical equations.



- LEGO® bricks of different sizes can be used to represent atoms with different valencies.
- For teacher demonstrations, it is recommended that the teacher uses the larger Duplo® LEGO® bricks.

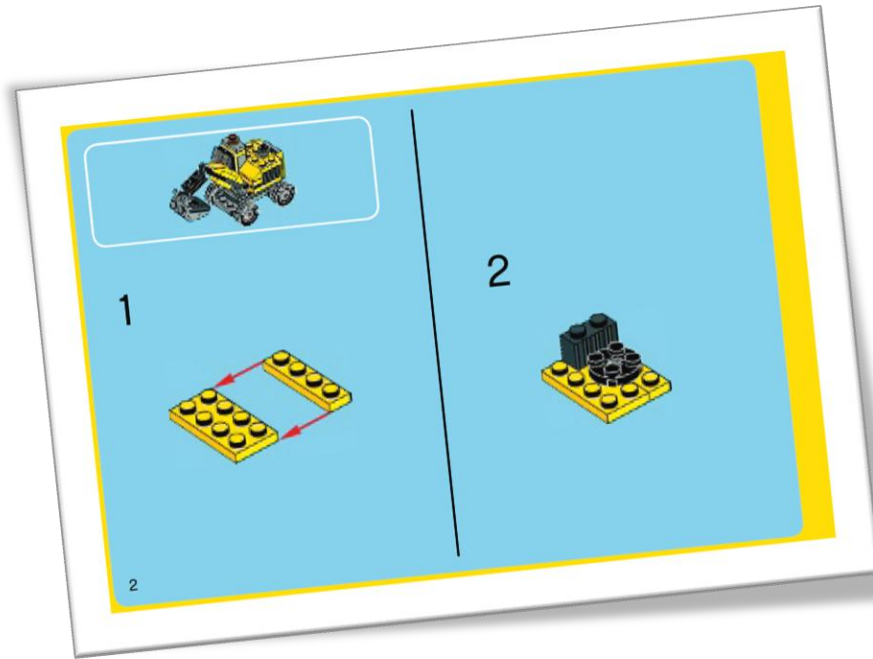
Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



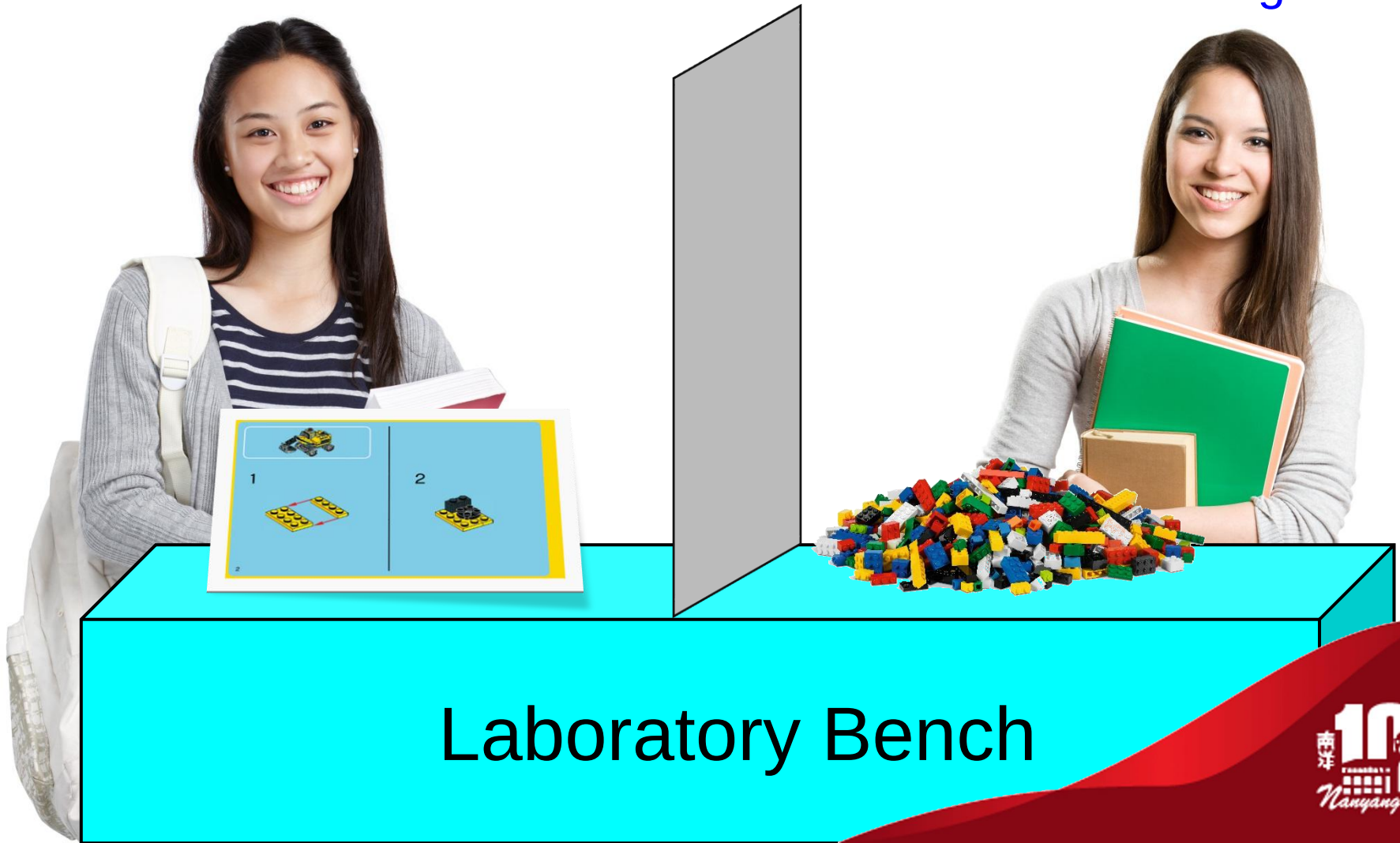
Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas

- Student #1 has the instructions

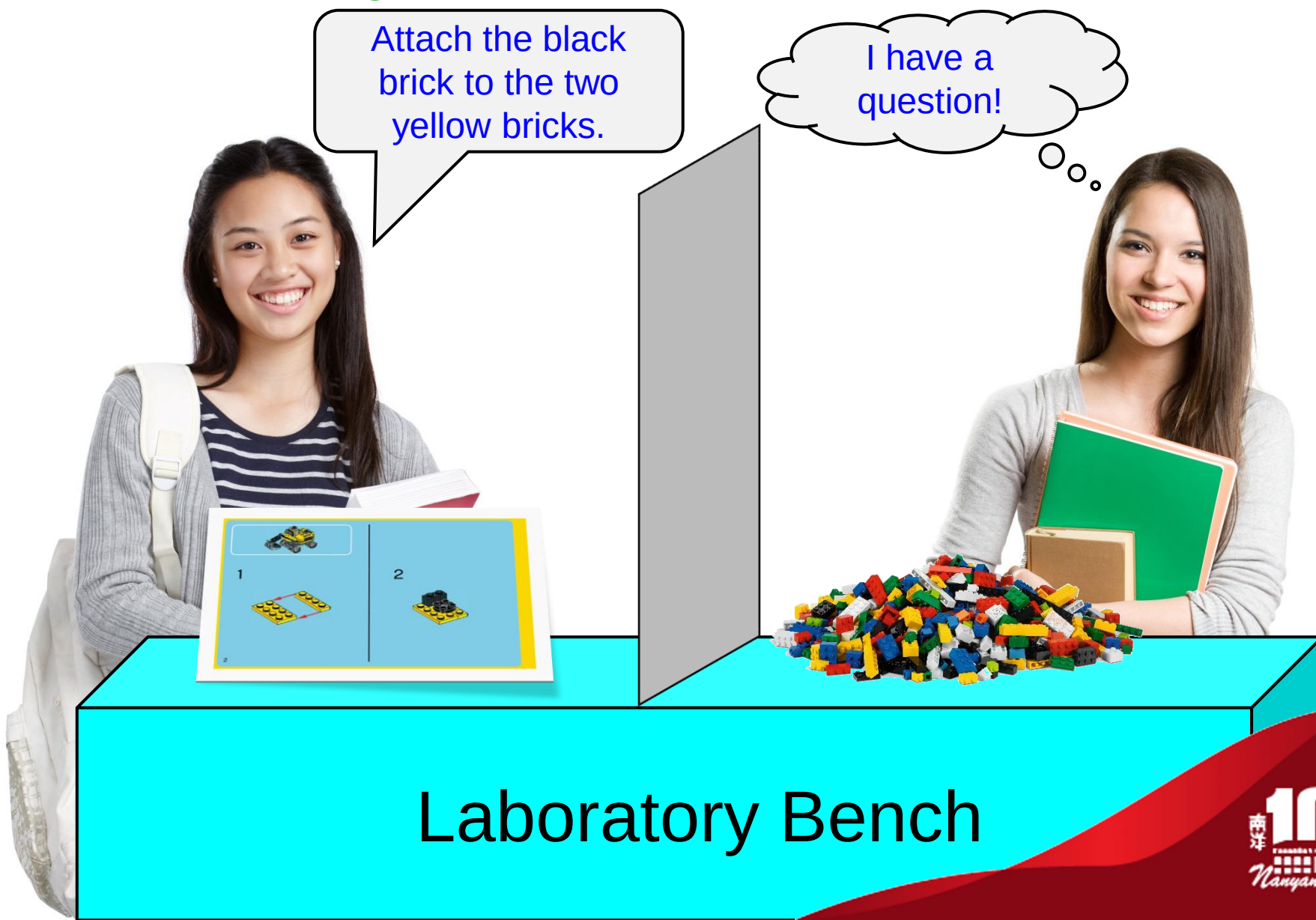
Screen

- Student #2 has the building bricks



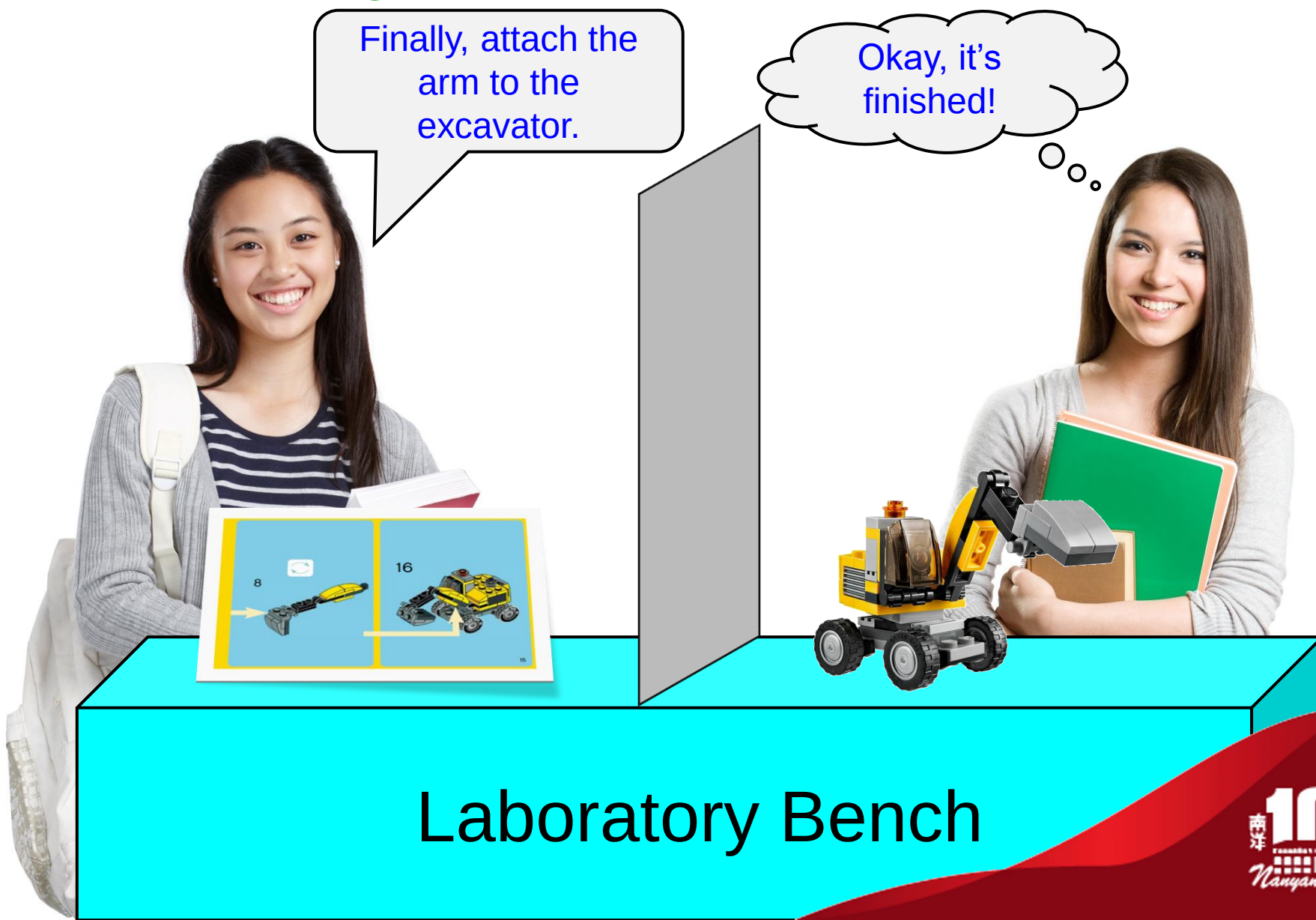
Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas



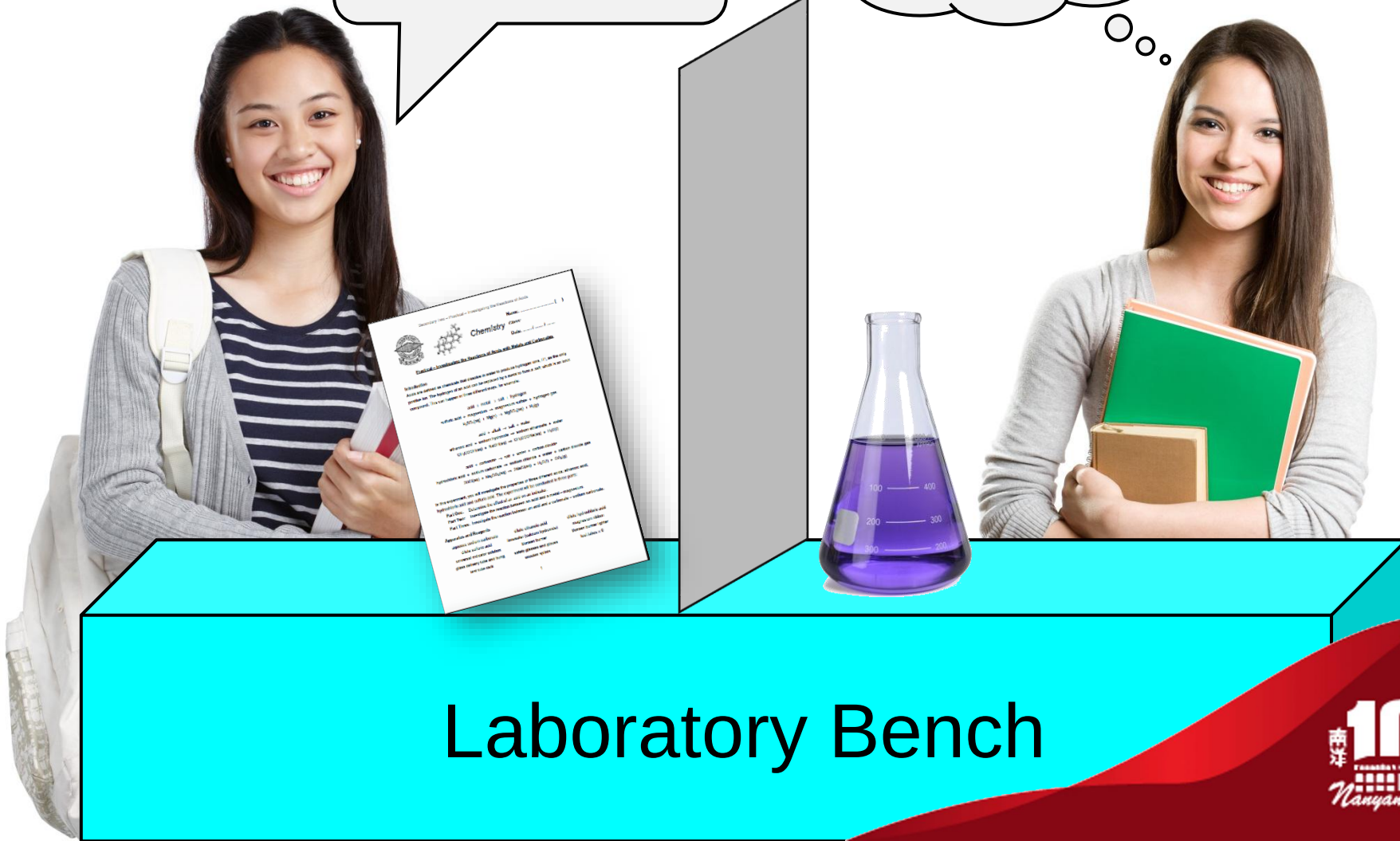
How does this help
a student succeed
in their planning of
an experiment?

Making Thinking Visible in Chemistry

17. Using LEGO® to Communicate Ideas

Take a conical flask
and then...

Wait! What
volume?



Laboratory Bench

Making Thinking Visible in Chemistry

18. Socratic Questioning

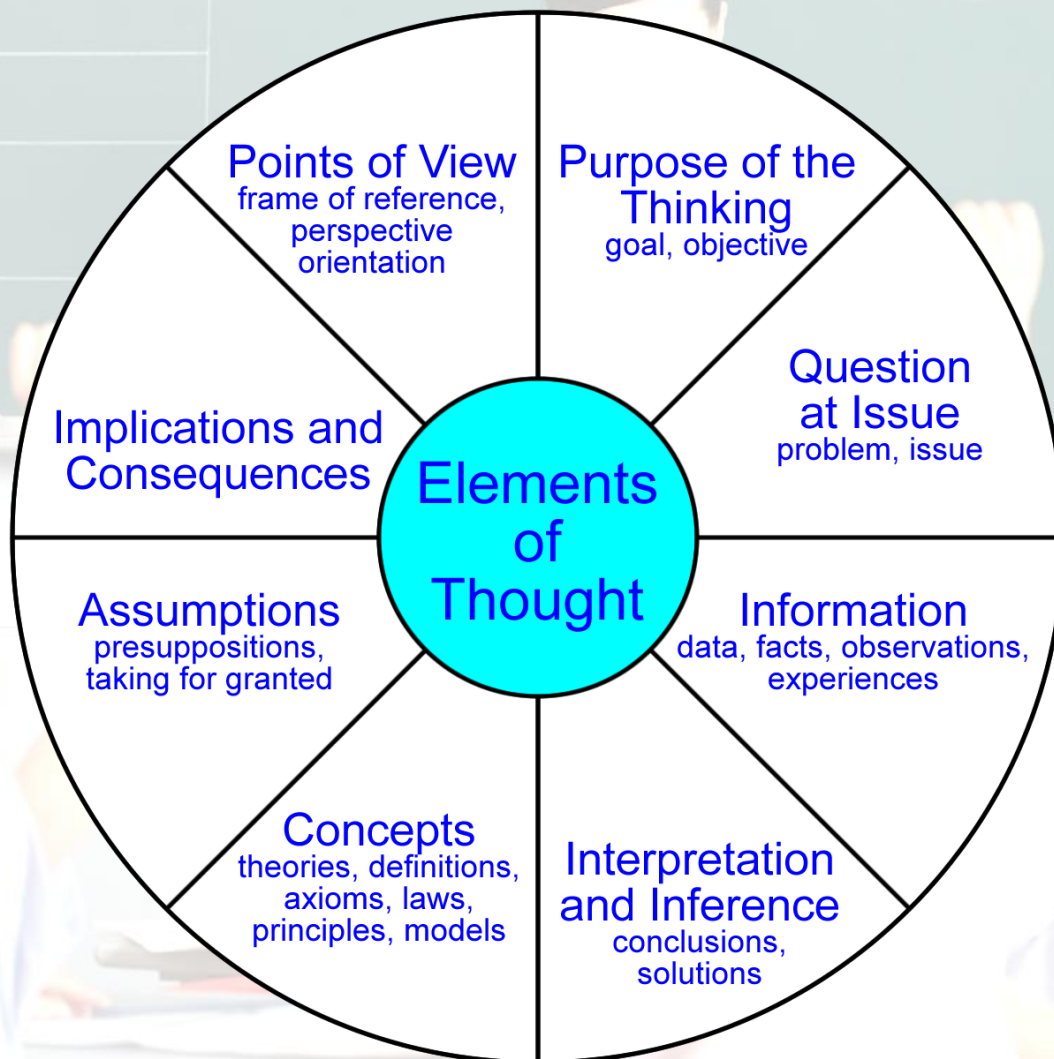


Home

Making Thinking Visible in Chemistry

18. Socratic Questioning

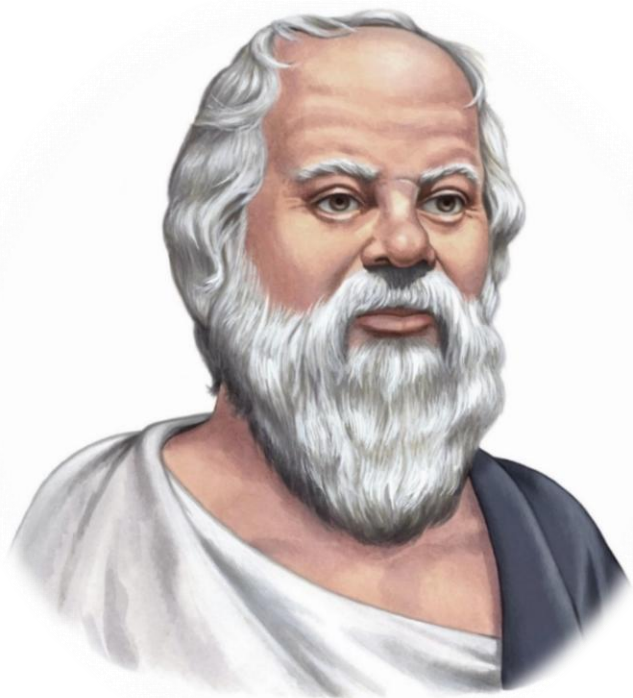
- Paul's Wheel of Reason.



- Guide to critical thinking.

Making Thinking Visible in Chemistry

18. Socratic Questioning



- Socrates,
Greek
Philosopher

Clarify

- Could you elaborate further?
- Could you give me an example?

Accuracy

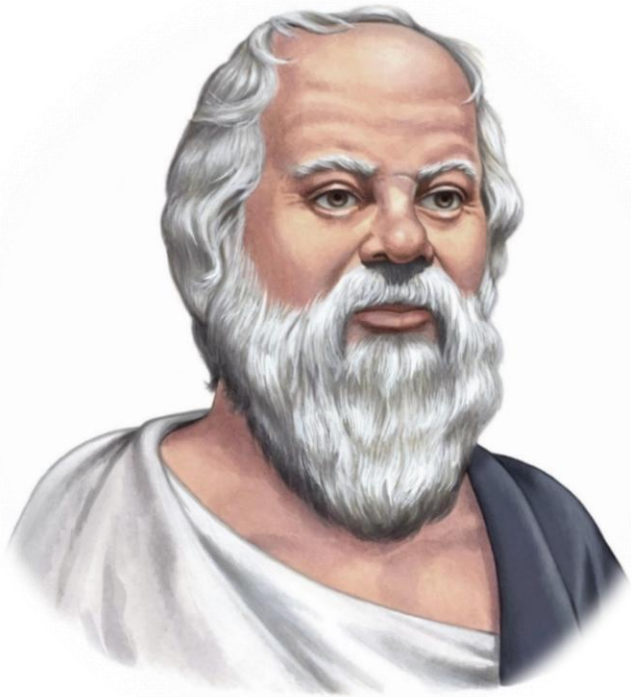
- How could we check on that?
- How could we verify or test that?

Precision

- Could you be more specific?
- Could you give me more details?

Making Thinking Visible in Chemistry

18. Socratic Questioning



- Socrates,
Greek
Philosopher

Relevance

- How does that relate to the problem?

Depth

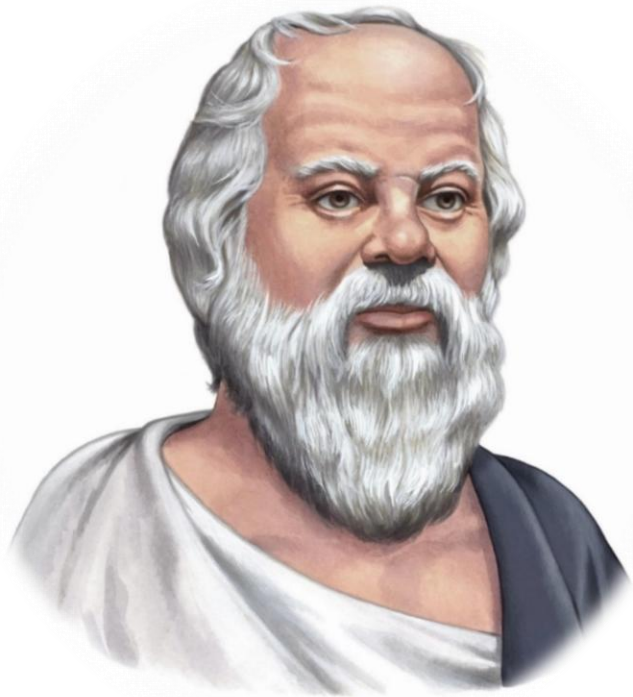
- What are some of the complexities of this problem?

Breadth

- What other perspectives should be considered?

Making Thinking Visible in Chemistry

18. Socratic Questioning



- Socrates,
Greek
Philosopher

Logic

- Does this all make sense?
- Does it all follow the evidence?

Significance

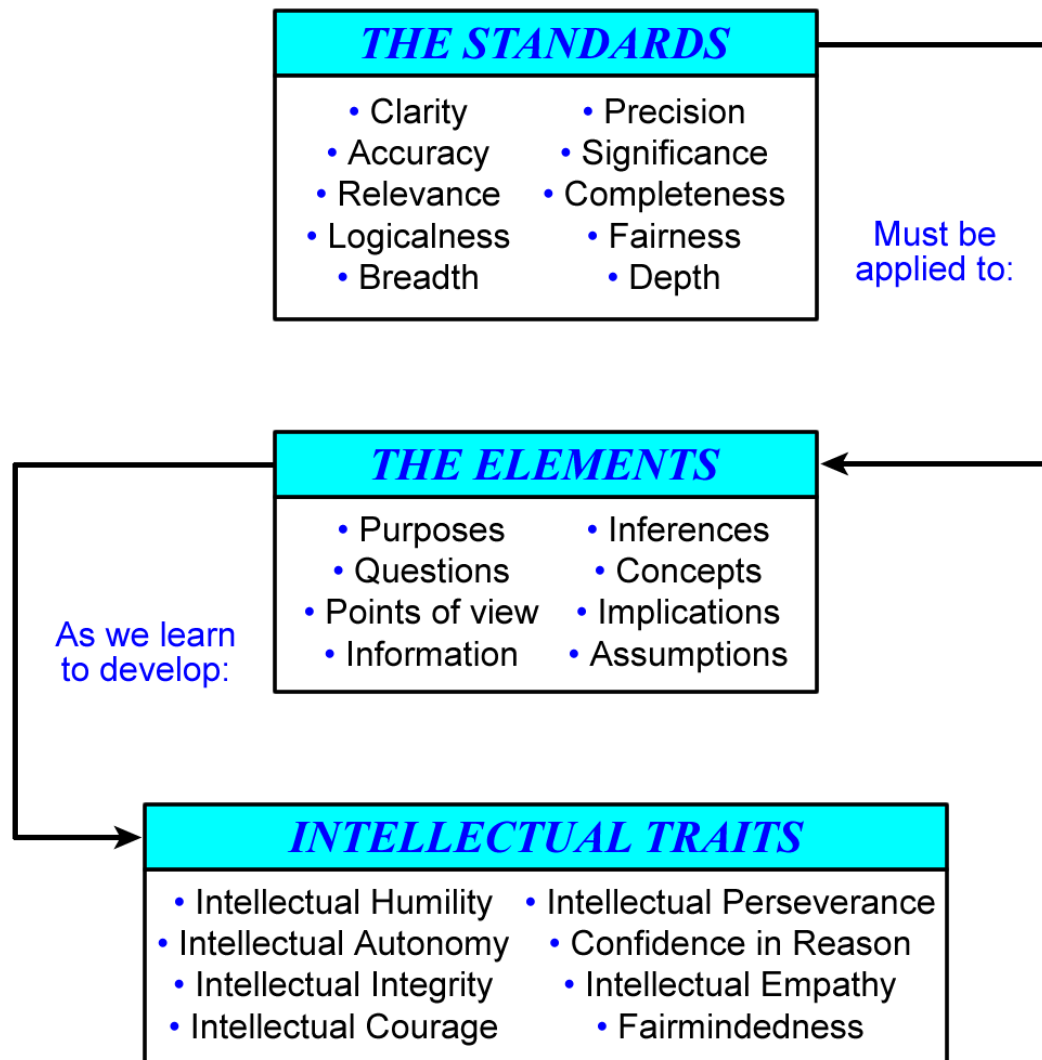
- Is this the most important problem to consider?

Fairness

- Do I have any vested interest in the issue?

Making Thinking Visible in Chemistry

18. Socratic Questioning



Making Thinking Visible in Chemistry

18. Socratic Questioning



- Question dice. These are made by Dr. Spencer Kagan for use as part of his cooperative learning strategies.

Making Thinking Visible in Chemistry

19. Teachers Model Critical and Creative Thinking



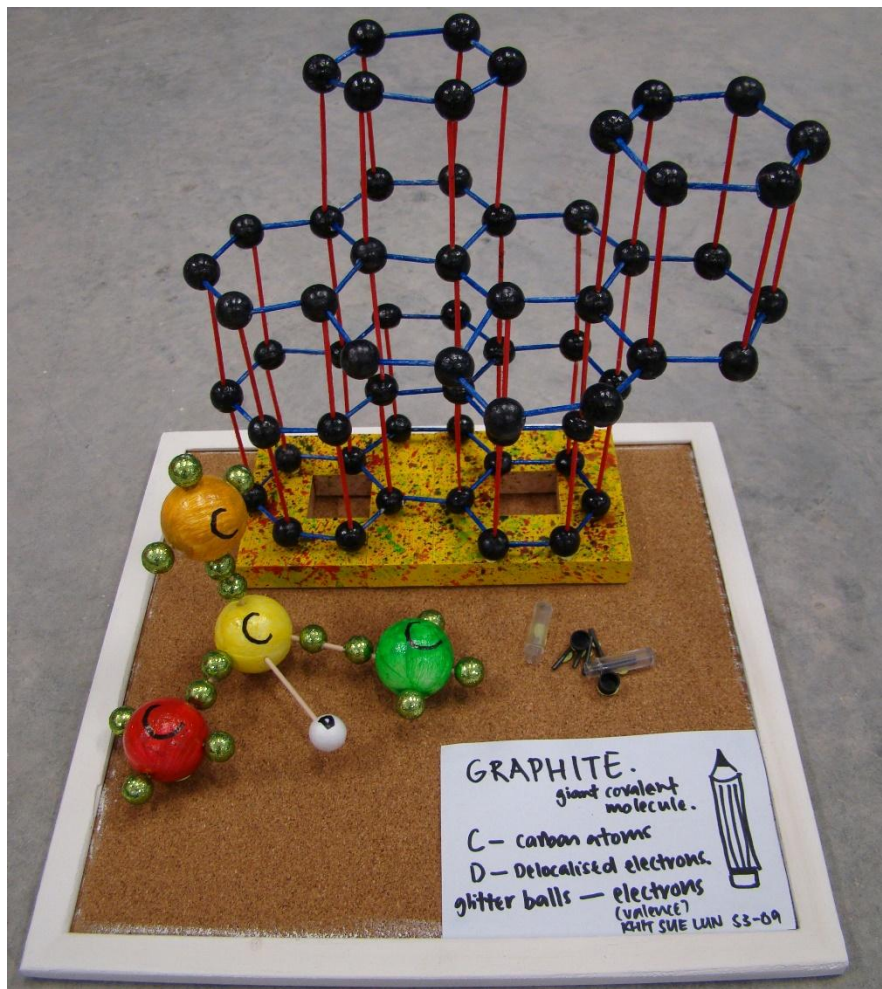
Making Thinking Visible in Chemistry

19. Teachers Model Critical and Creative Thinking

- Teachers often tell their students to “*think about it*” or “*think harder*” or “*think about it again*” without ever explaining to their students how to think.
- One solution is for teachers to *model good thinking practices* for their students by thinking out loud.
 - Teachers can model good thinking routines by verbalising what they are thinking while solving a problem. Teachers could try to approach the problem from the point-of-view of the student, asking themselves “*what?*” “*how?*” and “*why?*” questions.
 - Teachers could also make *purposeful mistakes* which they reason through and correct.

Making Thinking Visible in Chemistry

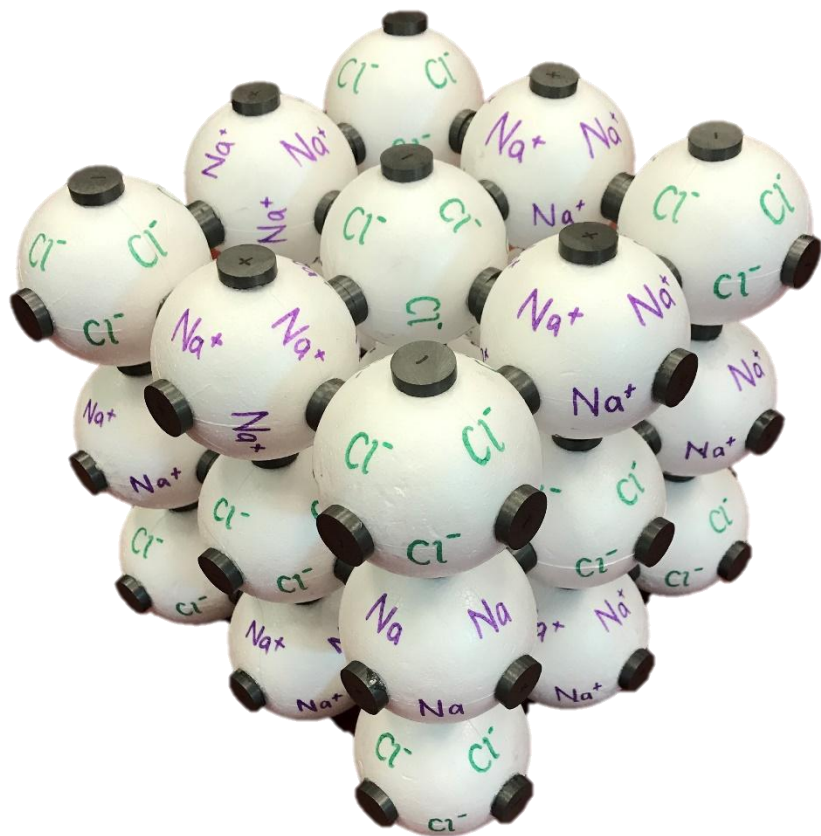
20. Authentic Transfer Task



- Students can make their thinking and understanding of a concept visible through authentic transfer tasks.
- Students transfer their knowledge and understanding of Chemistry to solve an authentic problem.

Making Thinking Visible in Chemistry

20. Authentic Transfer Task



- In this examples, students work in pairs to design and construct a model that clearly shows the bonding in an everyday substance.
- The model allows students to make their thinking visible, and allows their teacher to check for mistakes in their students' understanding.

Making Thinking Visible in Chemistry

20. Authentic Transfer Task



- Are there any errors in this model?

Making Thinking Visible in Chemistry

21. Modelling Kinetic Particle Theory

- Brownian Motion with a Beach Ball



- 9 minutes
10 seconds

- What are the limitations to the model?

Making Thinking Visible in Chemistry

21. Modelling Kinetic Particle Theory

- Diffusion with Balloons



- 9 minutes 10 seconds

- What are the limitations to the model?

Making Thinking Visible in Chemistry

22. Modelling Rate of Reaction

 **Chem!stry** Name: _____ ()
Class: _____
Date: ____/____/____

An Introduction to Reaction Kinetics – Macroconcept: Models

Step One:
Hydrogen gas (H_2) is mixed with chlorine gas (Cl_2).

Step Two:
A molecule of hydrogen gas ($H-H$) collides with a molecule of chlorine gas ($Cl-Cl$). If the molecules collide with **sufficient energy** (equal to or greater than the activation energy) and with the **correct orientation**, then a **reaction** will take place.

Step Three:
Energy is required (endothermic) to break the covalent bonds between the two atoms of hydrogen:
 $H-H_{(g)} \rightarrow H_{(g)} + H_{(g)}$
and the two atoms of chlorine:
 $Cl-Cl_{(g)} \rightarrow Cl_{(g)} + Cl_{(g)}$

Step Four:
Once the covalent bonds have been broken, the individual hydrogen atoms and chlorine atoms are able to change their positions relative to one another.

Step Five:
Energy is released (exothermic) as new covalent bonds form between the atoms of hydrogen and the atoms of chlorine:
 $H_{(g)} + Cl_{(g)} \rightarrow H-Cl_{(g)}$

Step Six:
Two molecules of hydrogen chloride gas are formed.
The overall balanced chemical equation is:
 $H_{2(g)} + Cl_{2(g)} \rightarrow 2HCl_{(g)}$

1

Model the Reaction Between Hydrogen and Chlorine

As you try you will need to move to a safe, open space. As a class, model how the chemical reaction between hydrogen gas (white balloons) and chlorine gas (green balloons) will take place. These colours have been chosen because they conform to the guidelines in the Applied Chemistry's guidelines which govern the use of colours in the classroom.

Describe the reaction between hydrogen and chlorine under each of the following conditions. Think about why you have chosen to move and how you have used your thoughts and ideas. Think about why you have chosen to move and how you have used your thoughts and ideas. Think about why you have chosen to move and how you have used your thoughts and ideas.

Scientific explanation of how this condition affects the rate of the chemical reaction:

2

Contrast the Model of the Chemical Reaction with Reality
(Robert Swartz and Stephen Fehner)

Help scientists to understand both complex and abstract concepts. All models have limitations and weaknesses. Use the template given below to contrast the model of the chemical reaction between hydrogen and chlorine with what you know about the reality of the reaction.

Reality

How are they similar to each other?

How are they different from each other?

With regard to...

3

From Models in Chemistry to Models in Other Subjects

Group, choose one concept from your list and elaborate on your idea to show how it could be used in a real-world situation. The group will then discuss the abstract concept, therefore allowing everybody to have a clear understanding of what is important.

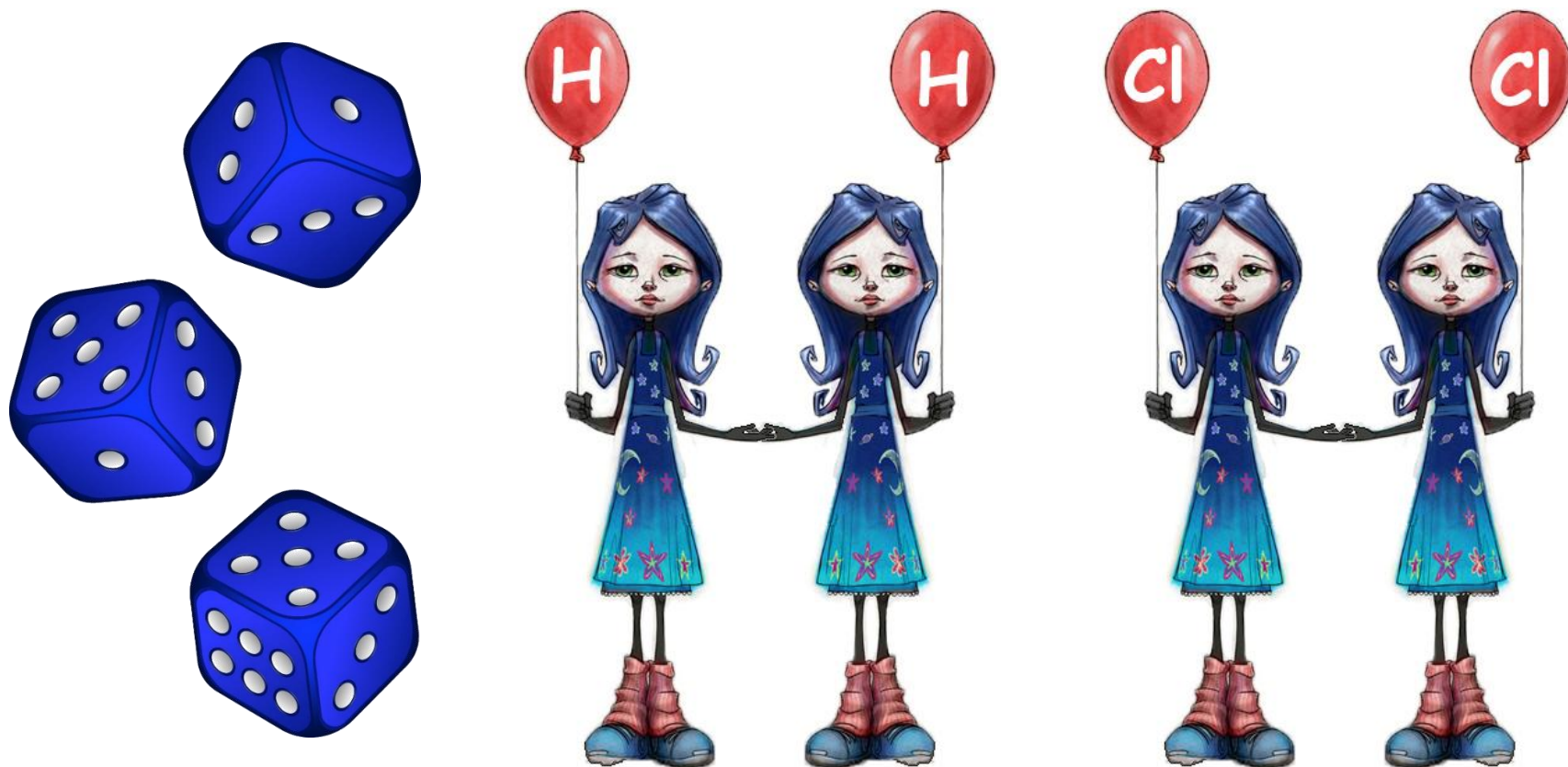
Identify the possible strengths and weaknesses of the model that you have proposed.

To what extent does the model that you have proposed resemble the model that was used to illustrate the reaction between hydrogen and chlorine?

4

Making Thinking Visible in Chemistry

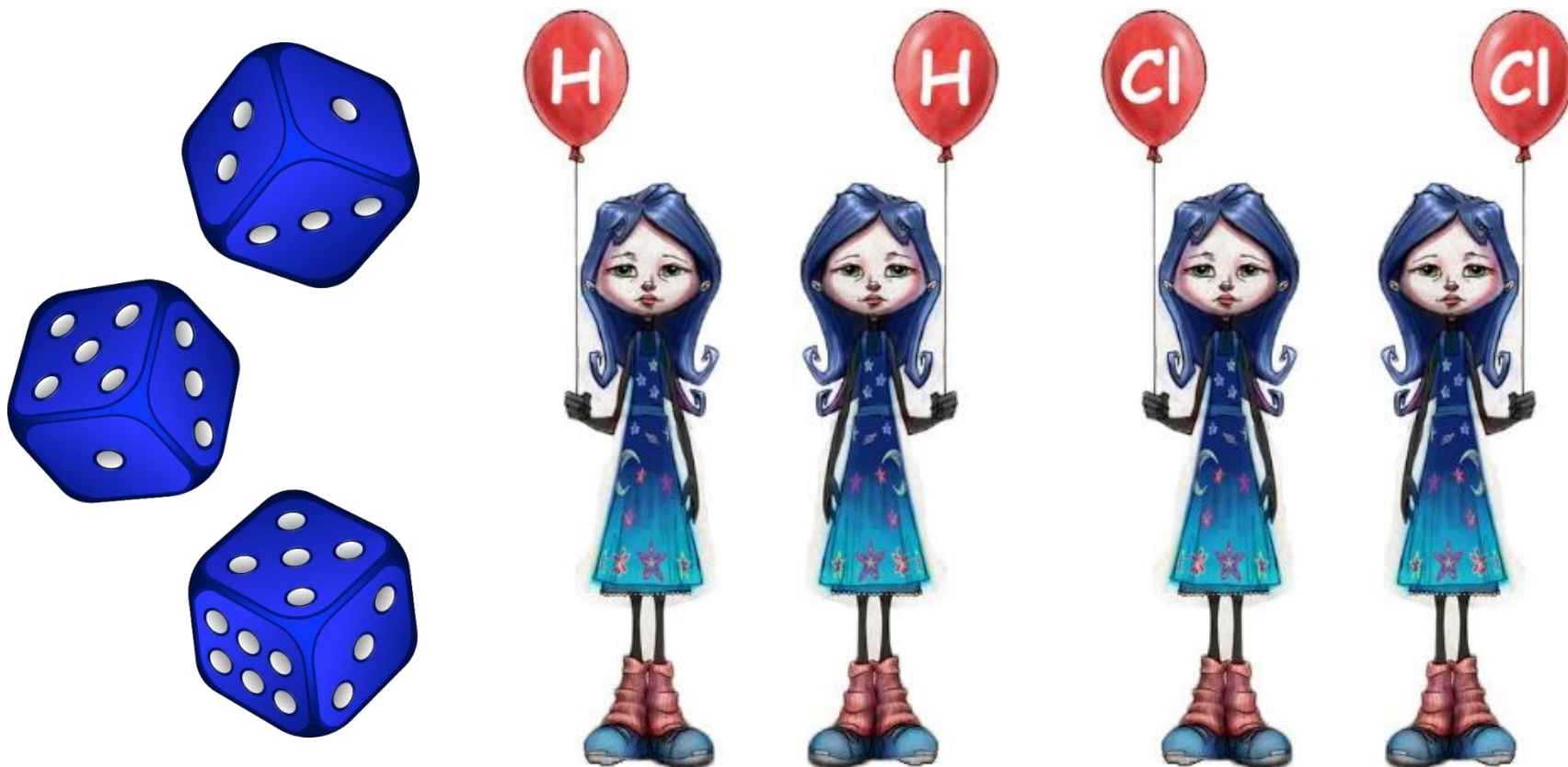
22. Modelling Rate of Reaction



- Students model the reaction between hydrogen and chlorine.

Making Thinking Visible in Chemistry

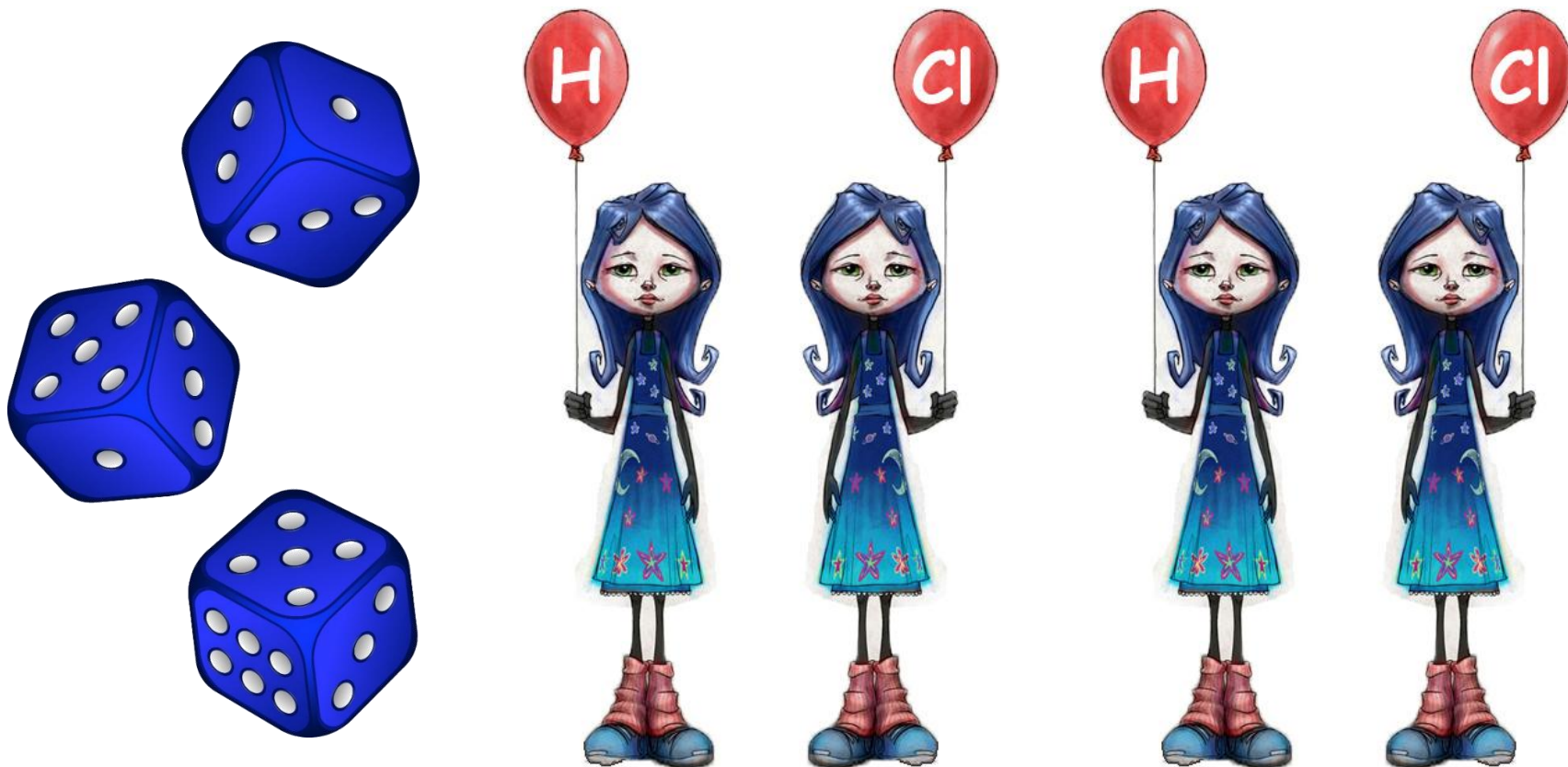
22. Modelling Rate of Reaction



- Each pair of students, H_2 and Cl_2 have a six-sided die.

Making Thinking Visible in Chemistry

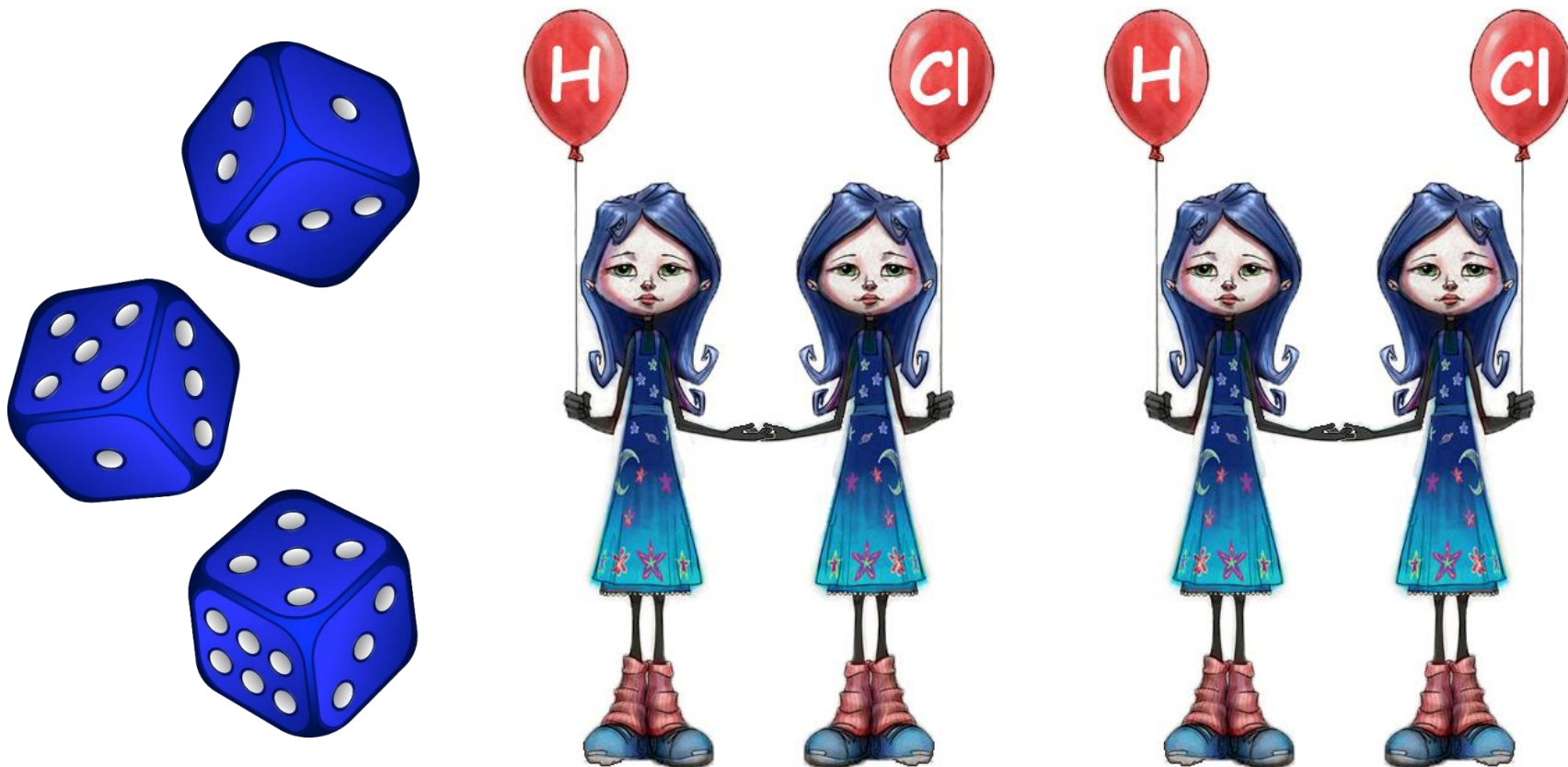
22. Modelling Rate of Reaction



- Students roll the die in order to determine whether or not they react.

Making Thinking Visible in Chemistry

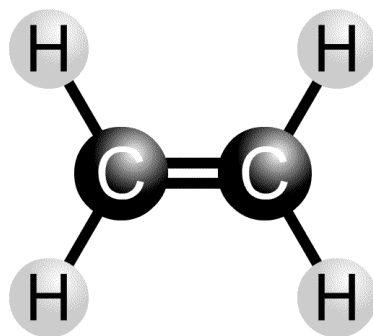
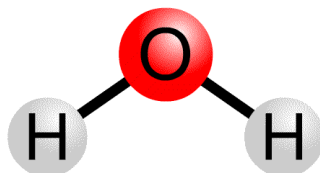
22. Modelling Rate of Reaction



- For example, with unfavourable reaction conditions, both H_2 and Cl_2 must roll “*six*”.

Making Thinking Visible in Chemistry

23. Animations

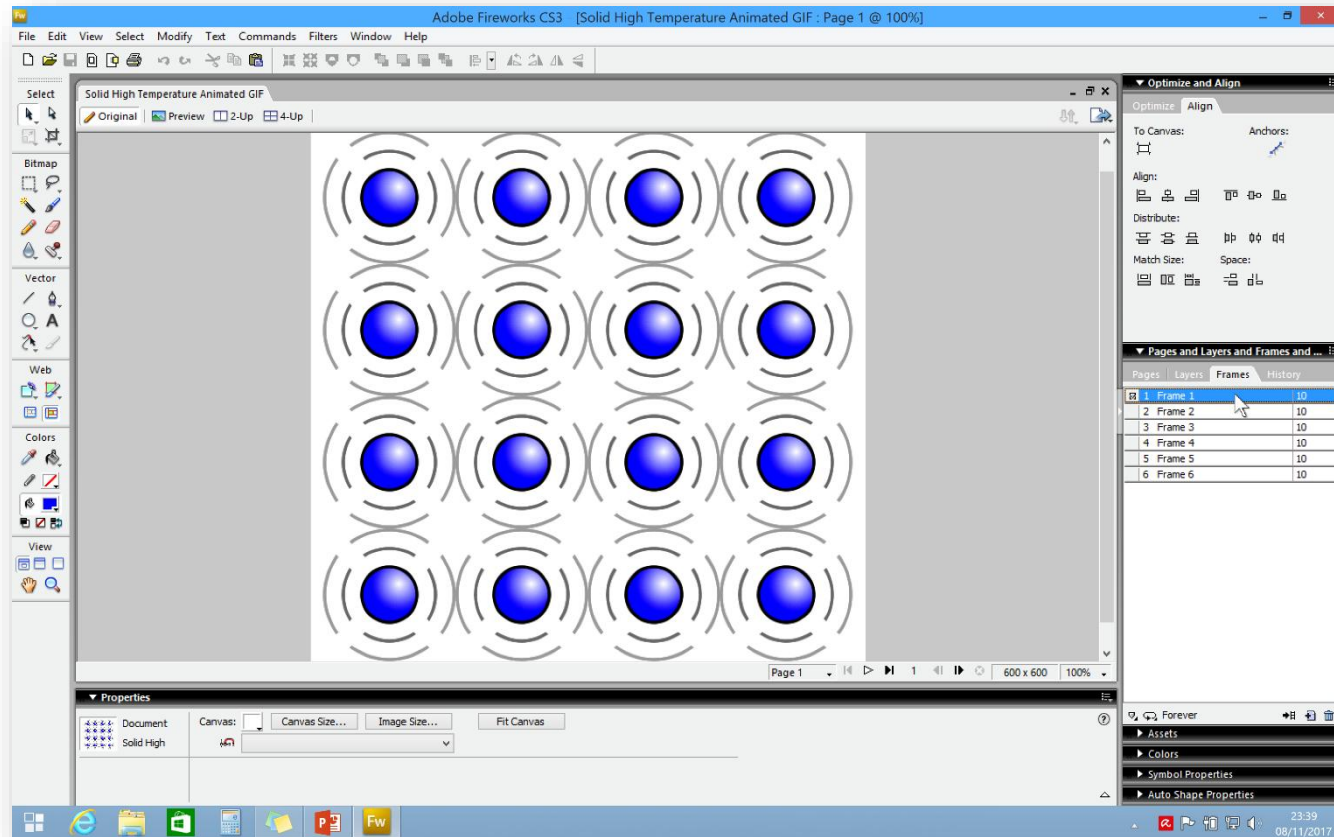


- Animations allow students to visualise and understand what is happening at a sub-microscopic level during a chemical reaction.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

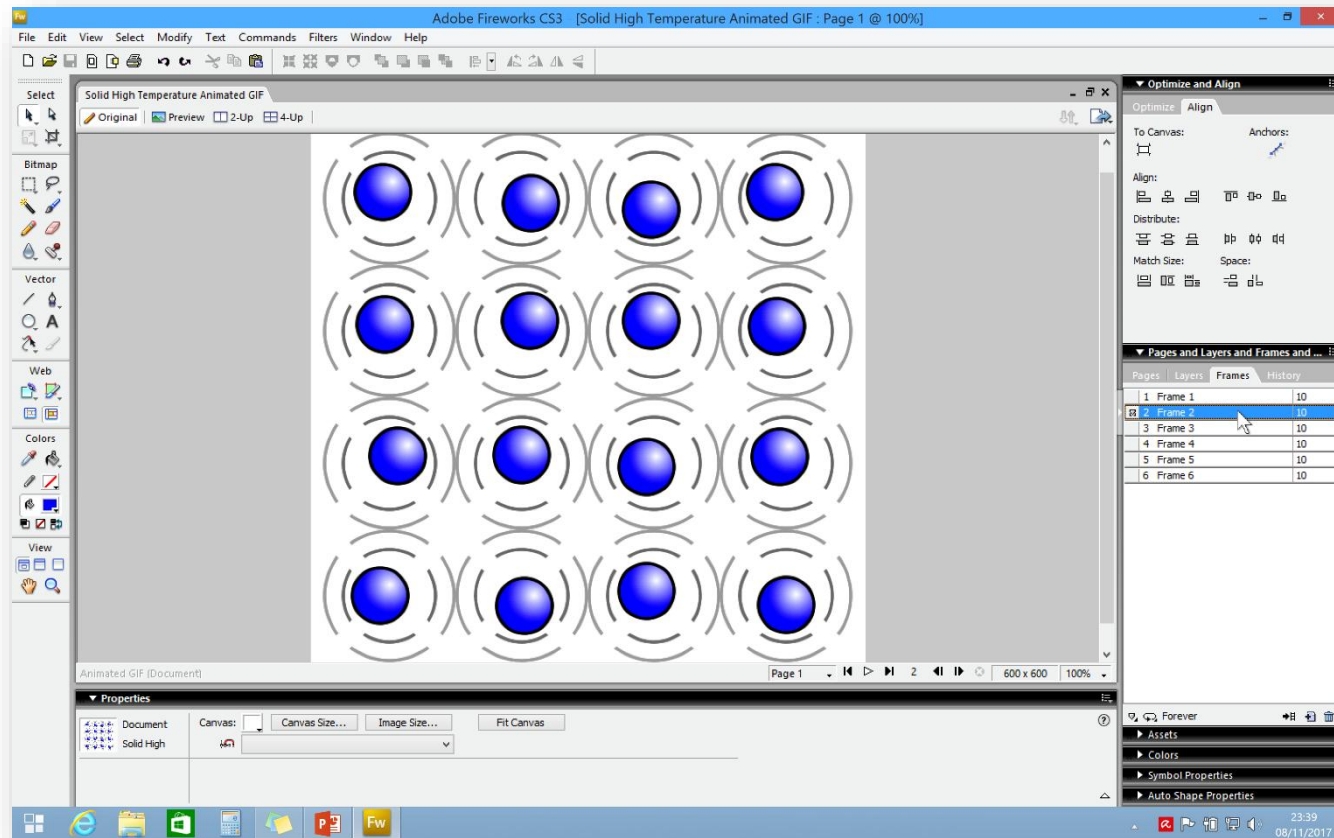


- Animated GIFs (graphics interchange format) are short, silent animations that loop continuously.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

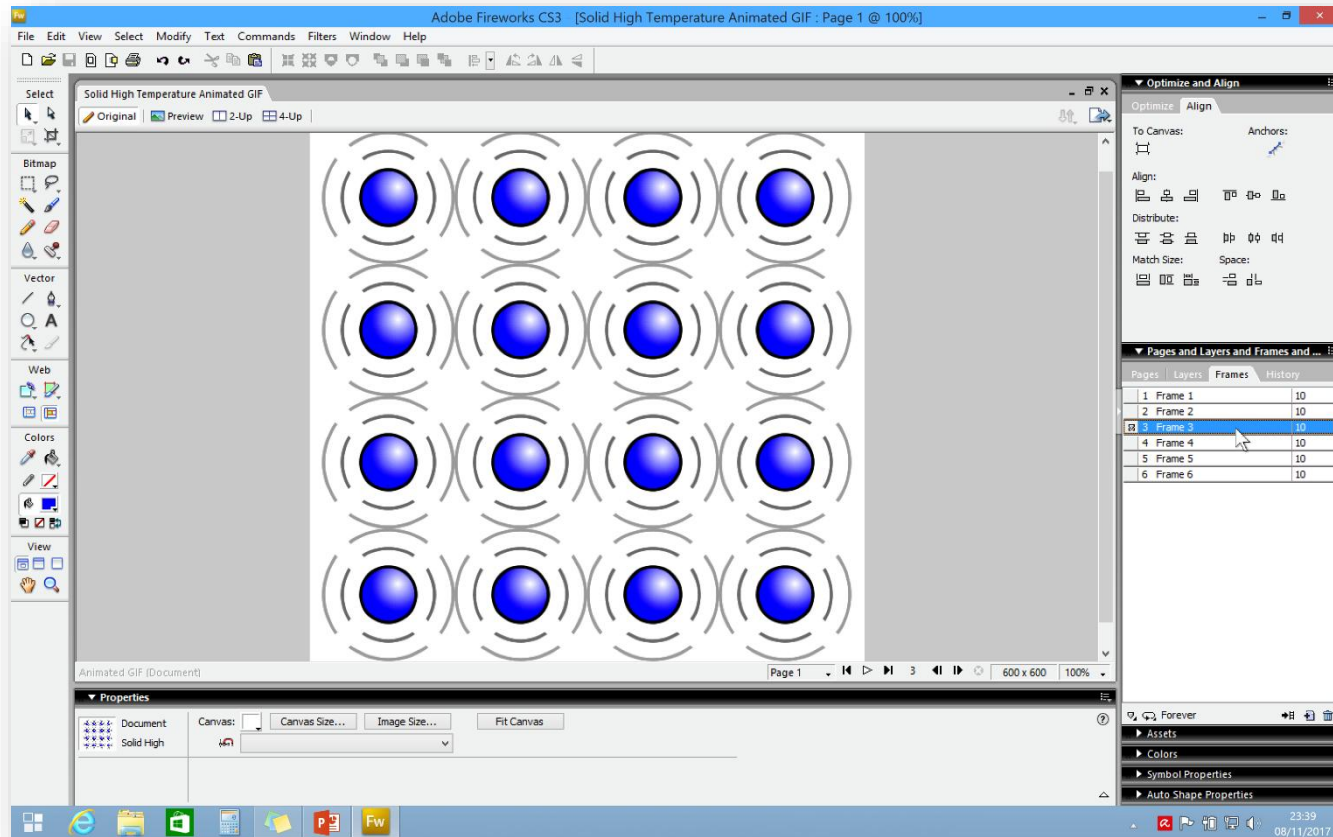


- Animated GIFs can be used to help students visualise how particles are moving and interacting.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

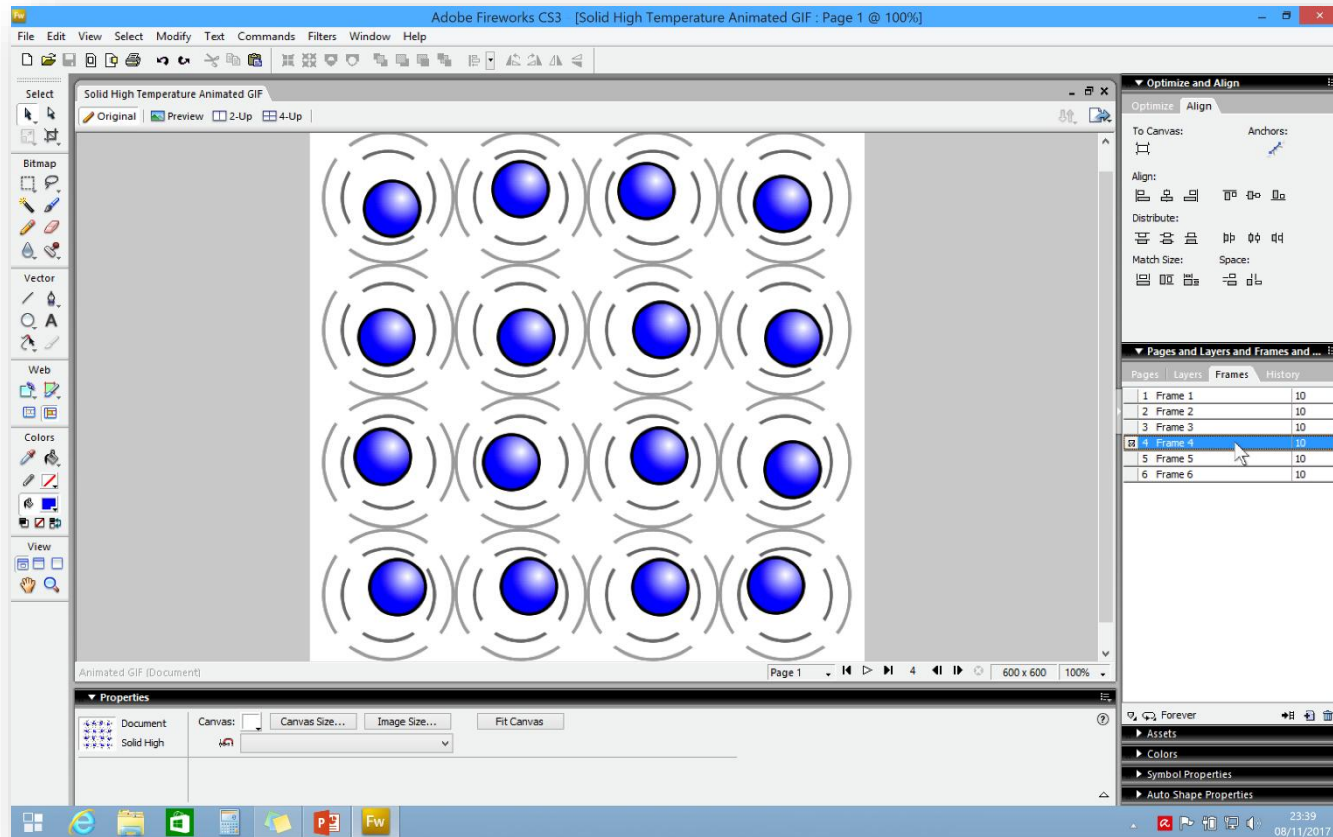


- Animated GIFs can be created using software such as Adobe Fireworks® and Adobe Photoshop®.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

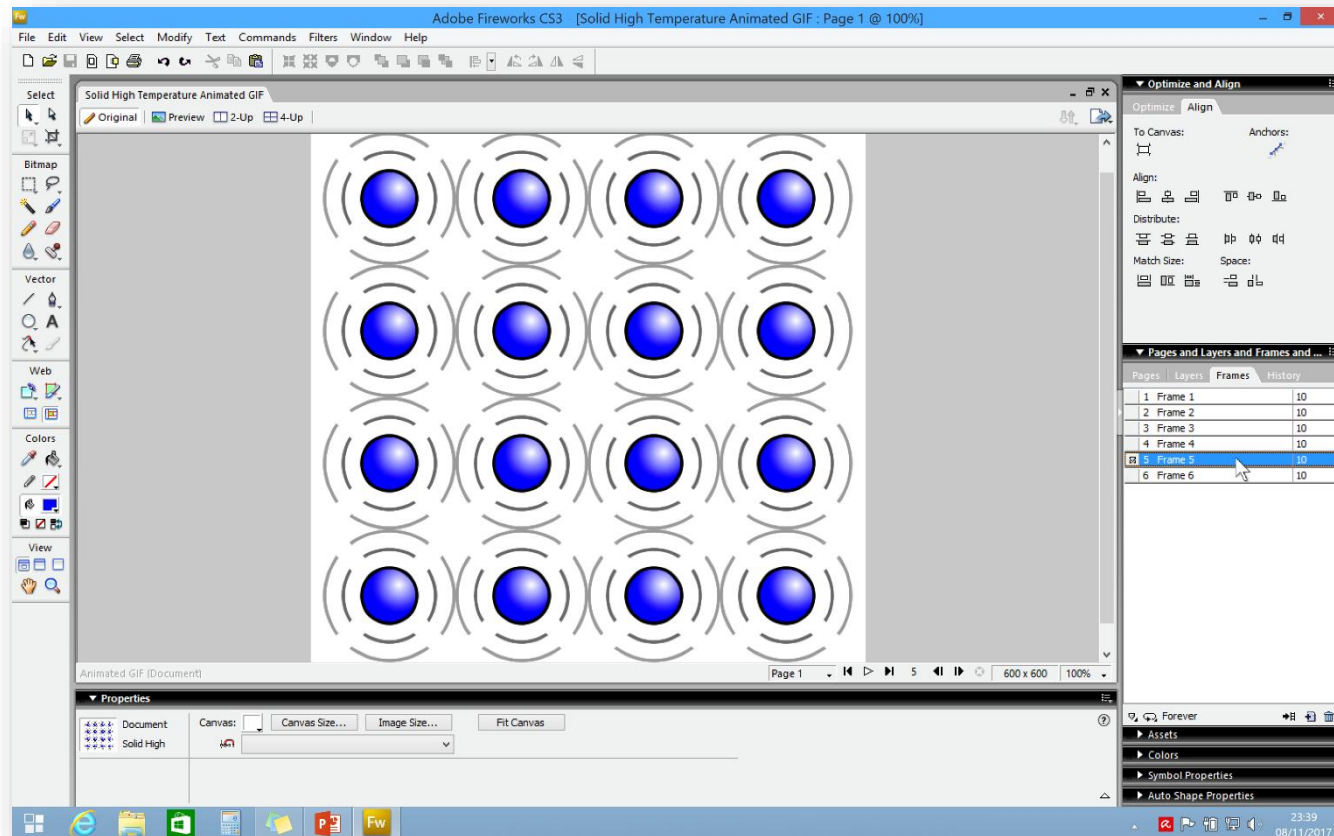


- Effective animated GIFs can be created from relatively simple drawings.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

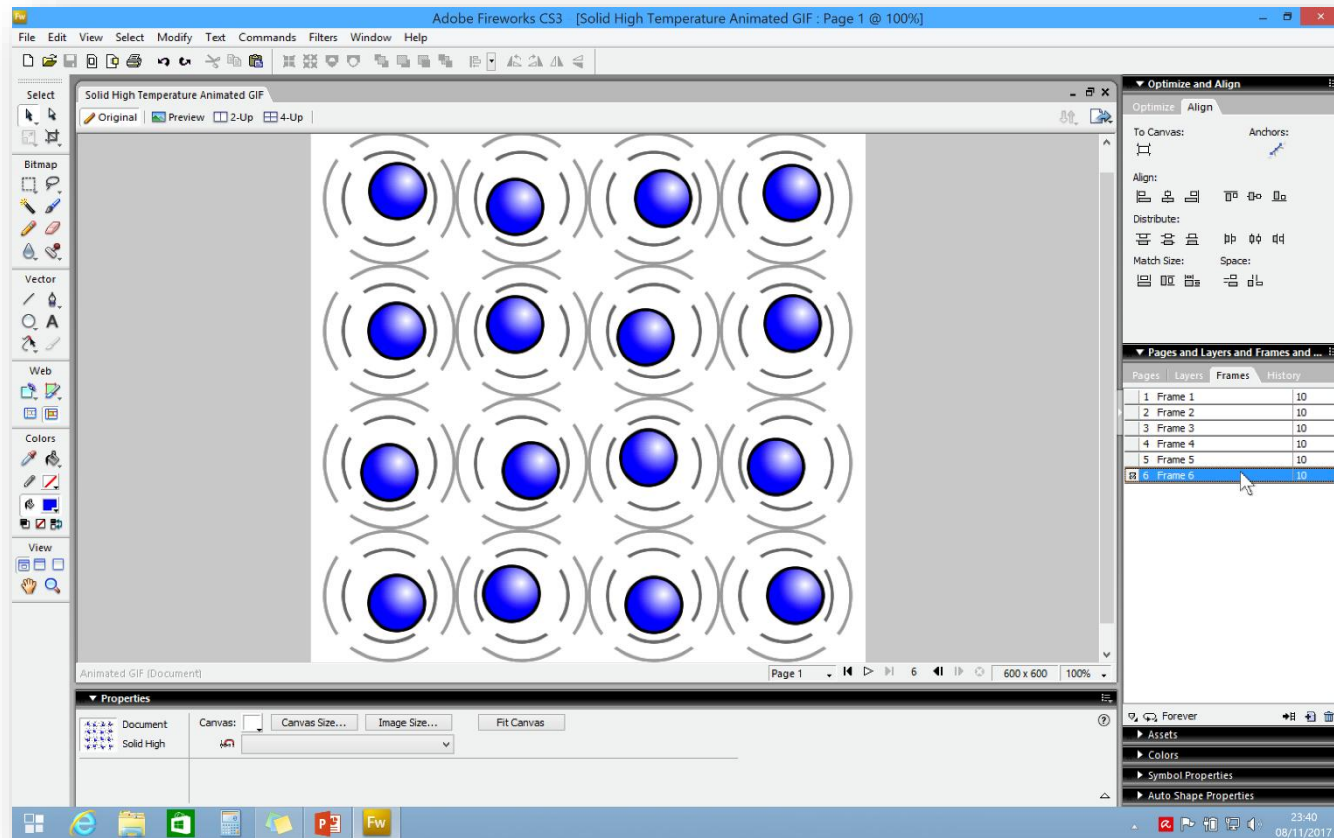


- An animated GIF is created by drawing different *frames*, which are then shown one-after-another.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs

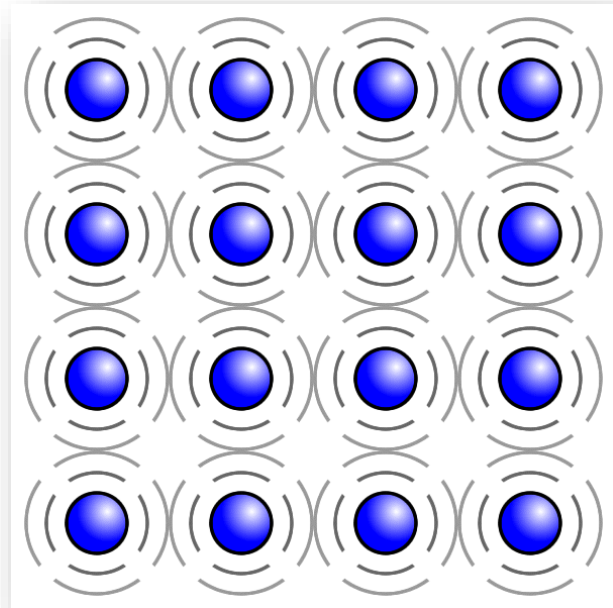
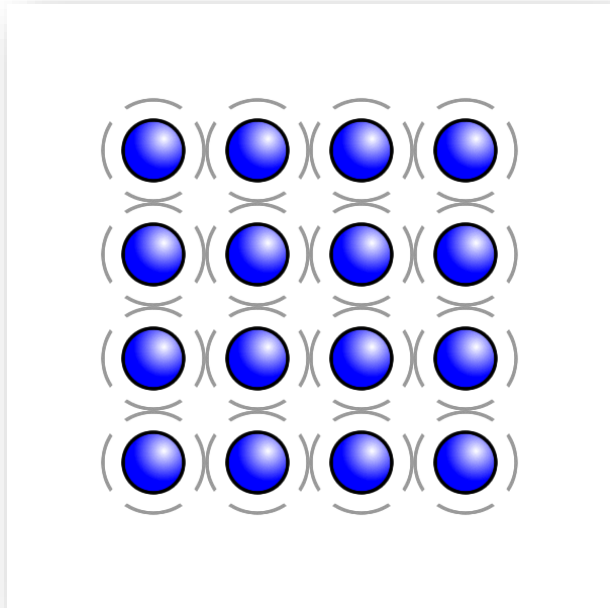


- The initial drawing is the first frame. The drawing is then modified and saved as the second frame, and so on.

Making Thinking Visible in Chemistry

23. Animations

- Stop-frame Animation to Create Animated GIFs



- These animated GIFs illustrate the movement of particles in solids at relatively low (left) and relatively high (right) temperatures, and maybe used to explain why solids expand on heating.

Making Thinking Visible in Chemistry

24. Traffic Lights



- Students are given three plastic cups, one red, one orange and one green – the same colours as a set of traffic lights.
- Students stack the three plastic cups on top of each other, with only the green cup visible.
- The three stacked cups are placed in a prominent position on each student's desk.

Making Thinking Visible in Chemistry

24. Traffic Lights



Making Thinking Visible in Chemistry

24. Traffic Lights

- The three cups are used by individual students to make their level of understanding visible during their Chemistry lesson.
- If the student is confident that they understand the lesson, then they leave the green cup on display.
- If the student starts to become unclear or unsure about the lesson, then they will change and have the orange cup on display.
- If the student is confused and unable to understand the lesson, then they will change and have the red cup on display.

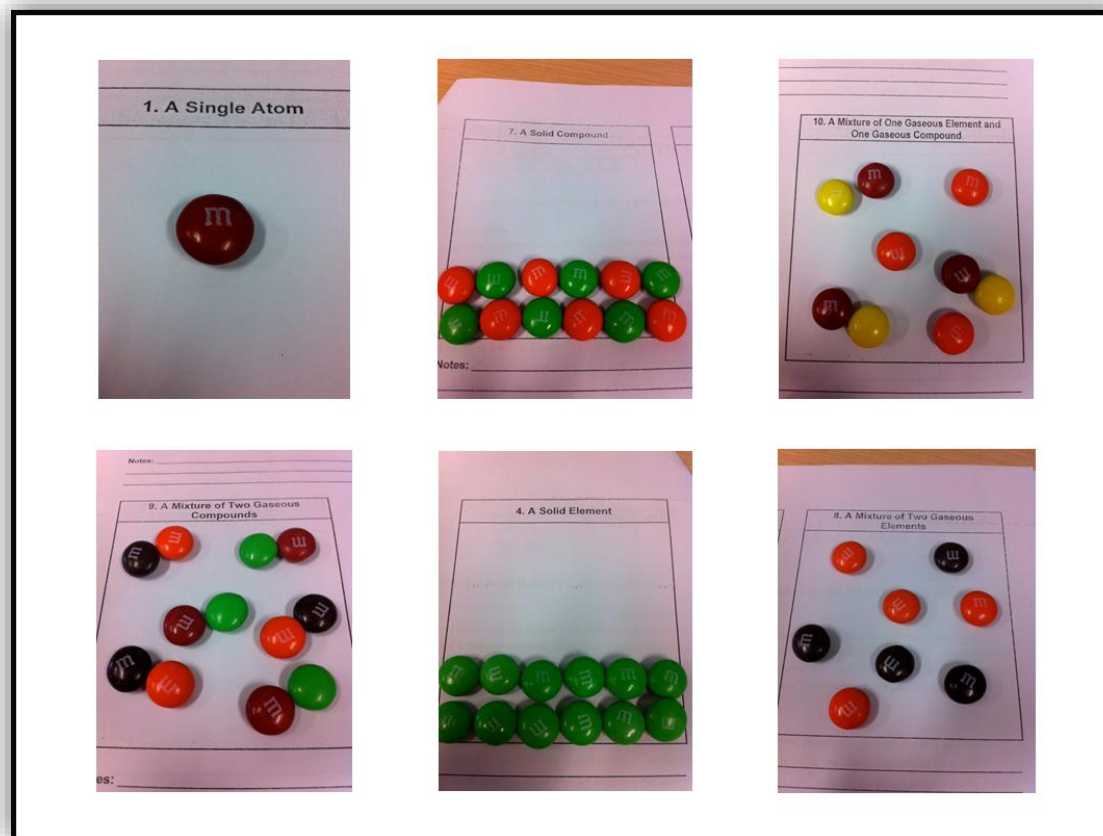
Making Thinking Visible in Chemistry

24. Traffic Lights

- When the teacher notices that a student has a red cup on display, then they may choose another student who has their green cup on display – and presumably understands what is going on – to explain the concept to the rest of the class.
- If the teacher notices that many students have orange or red cups displayed on their desk, then they may choose to re-teach the concept using a slightly different pedagogy.

Making Thinking Visible in Chemistry

25. Integration with Technology



- Students can make their thinking visible by sharing their work through online platforms. Here, a student is using M&M's to model their ideas.

Making Thinking Visible in Chemistry

25. Integration with Technology

Register Number 18.



1) Oxygen and Nitrogen in the air. Simple covalent. Low melting and boiling points. This is because the weak intermolecular forces break down easily.



3) Graphite. Giant covalent bonding. Graphite is a form of carbon in which the carbon atoms form layers. These layers can slide over each other.



2) Sodium chloride. Ionic compound. Ionic bonds are the electrostatic forces of attraction between oppositely charged ions. The oppositely charged ions are arranged in a regular way.



4) Aluminum. Metal bonding. Metals contain electrons that are free to move in the metal structure, carrying charge from place to place and allowing metals to conduct electricity well.

- In this example, a student is sharing their ideas about chemical bonding by uploading and commenting on their own photos of materials.

Making Thinking Visible in Chemistry

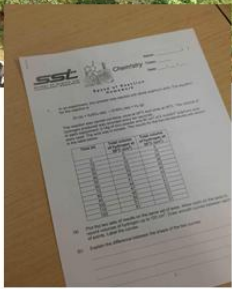
25. Integration with Technology

Organic

Cell wall is made of cellulose which is organic.



Most compounds in paper fibres are organic.



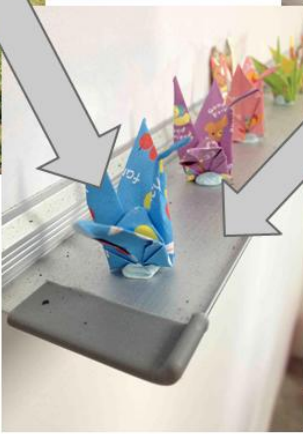
Inorganic

Metals are inorganic.



Synthetic fibres are inorganic.

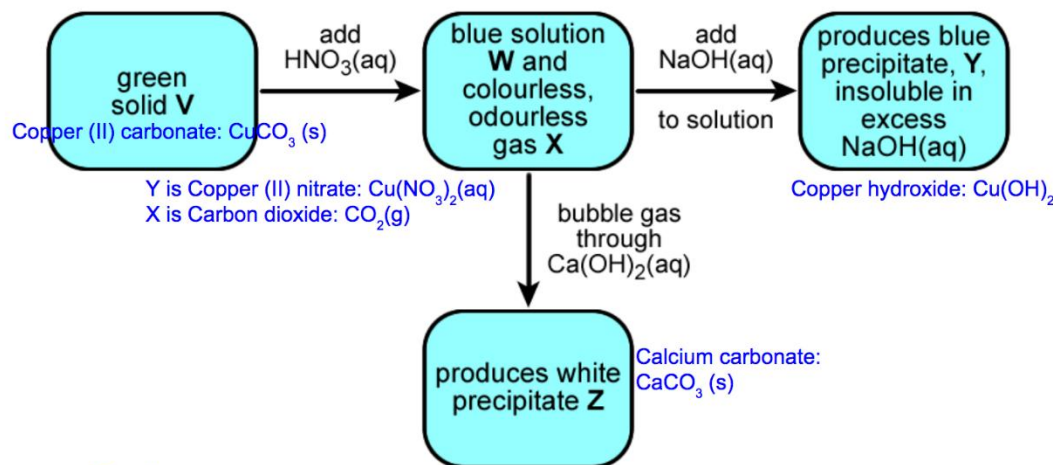




- In this example, a student is trying to define the concept of *organic*. Students can view and comment on each other's work.

Making Thinking Visible in Chemistry

25. Integration with Technology



Reactions

- $\text{CuCO}_3 (\text{s}) + 2\text{HNO}_3 (\text{aq}) \rightarrow \text{Cu}(\text{NO}_3)_2(\text{aq}) + \text{CO}_2 (\text{g}) + \text{H}_2\text{O}(\text{l})$
- $\text{Cu}(\text{NO}_3)_2 (\text{aq}) + \text{NaOH}(\text{s}) \rightarrow \text{Cu}(\text{OH})_2 (\text{s}) + 2\text{NaNO}_3 (\text{aq})$
- $\text{CO}_2 (\text{g}) + \text{Ca}(\text{OH})_2 \rightarrow \text{CaCO}_3(\text{s}) + \text{H}_2\text{O}(\text{l})$



Christopher
7:15 AM Today

Resolve

Please check the formula and state symbol for sodium hydroxide.

- In this example, students solve problems on qualitative analysis in a shared Google Slide. Note the incorrect formula and state symbol for sodium hydroxide, $\text{Na}(\text{OH})_2(\text{s})$.

Making Thinking Visible in Chemistry

25. Integration with Technology

CH

What is the laboratory preparation of sodium chloride?



In the laboratory, sodium chloride (NaCl) can be prepared through a neutralization reaction between a strong acid and a strong base. A common method involves reacting sodium hydroxide (NaOH) with hydrochloric acid (HCl). Here's a step-by-step guide to prepare sodium chloride in the lab:



- In another activity, students suggest ways of preparing different salts in the laboratory.

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25. Integration with Technology

CH

What is the laboratory preparation of silver chloride?



Silver chloride (AgCl) is an insoluble salt that can be prepared in the laboratory through a double displacement (precipitation) reaction. It is typically formed by reacting silver nitrate (AgNO_3) with sodium chloride (NaCl) or another chloride salt. Here's a step-by-step guide to prepare silver chloride in the lab:



- Students type their suggestions into a shared Google document or Padlet for peer review.

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25. Integration with Technology

CH

What is the laboratory preparation of copper(II) chloride?



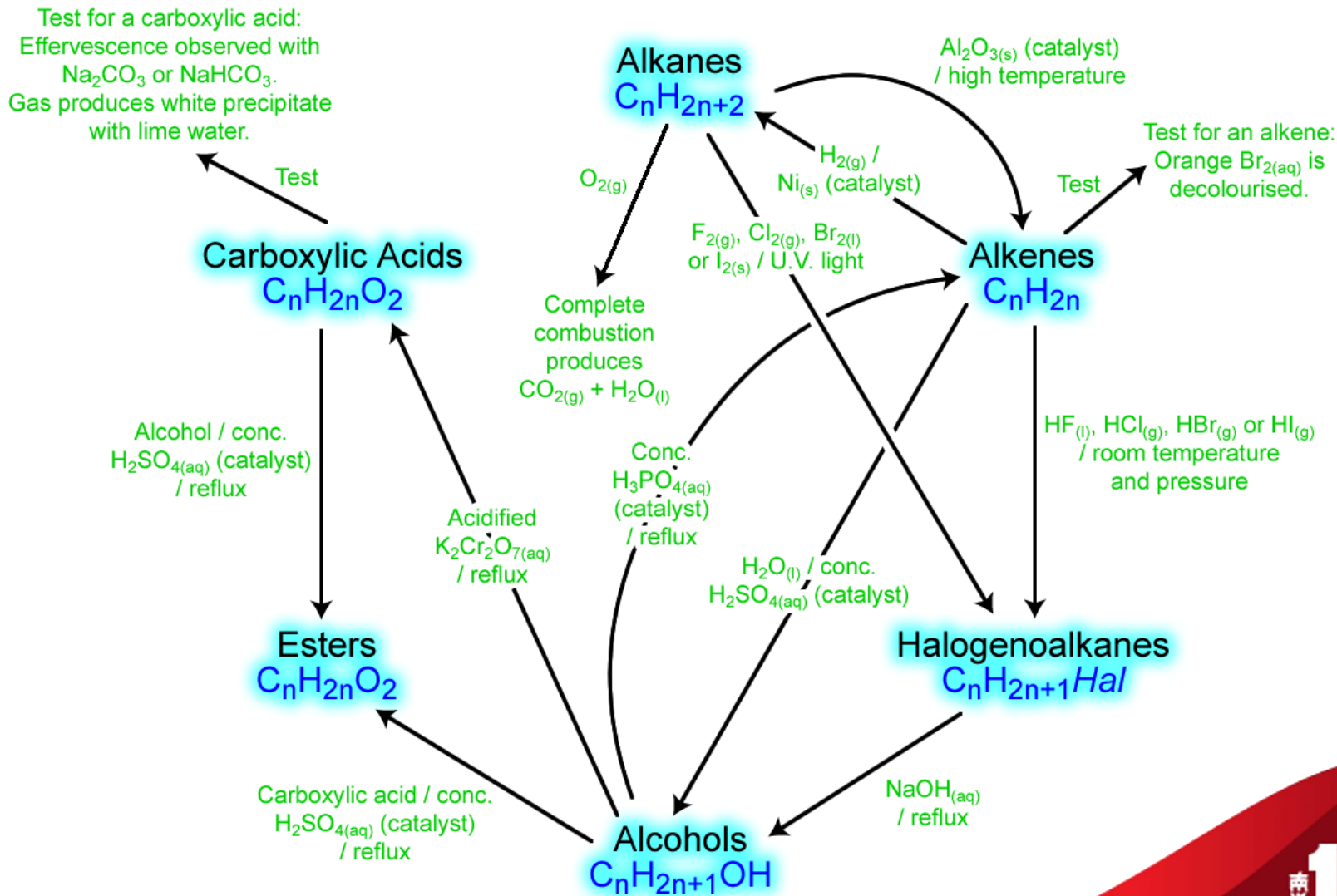
Copper(II) chloride (CuCl_2) can be prepared in the laboratory through a single displacement reaction or by reacting copper(II) oxide or copper(II) hydroxide with hydrochloric acid. Here are two methods for preparing copper(II) chloride in the lab:



- Finally, ChatGPT-4 is asked to suggest the best way of preparing the same salt in the laboratory.
- Students review the answers provided by the artificial intelligence (AI) and compare to their own, looking for errors in their own work, and the work of the AI.

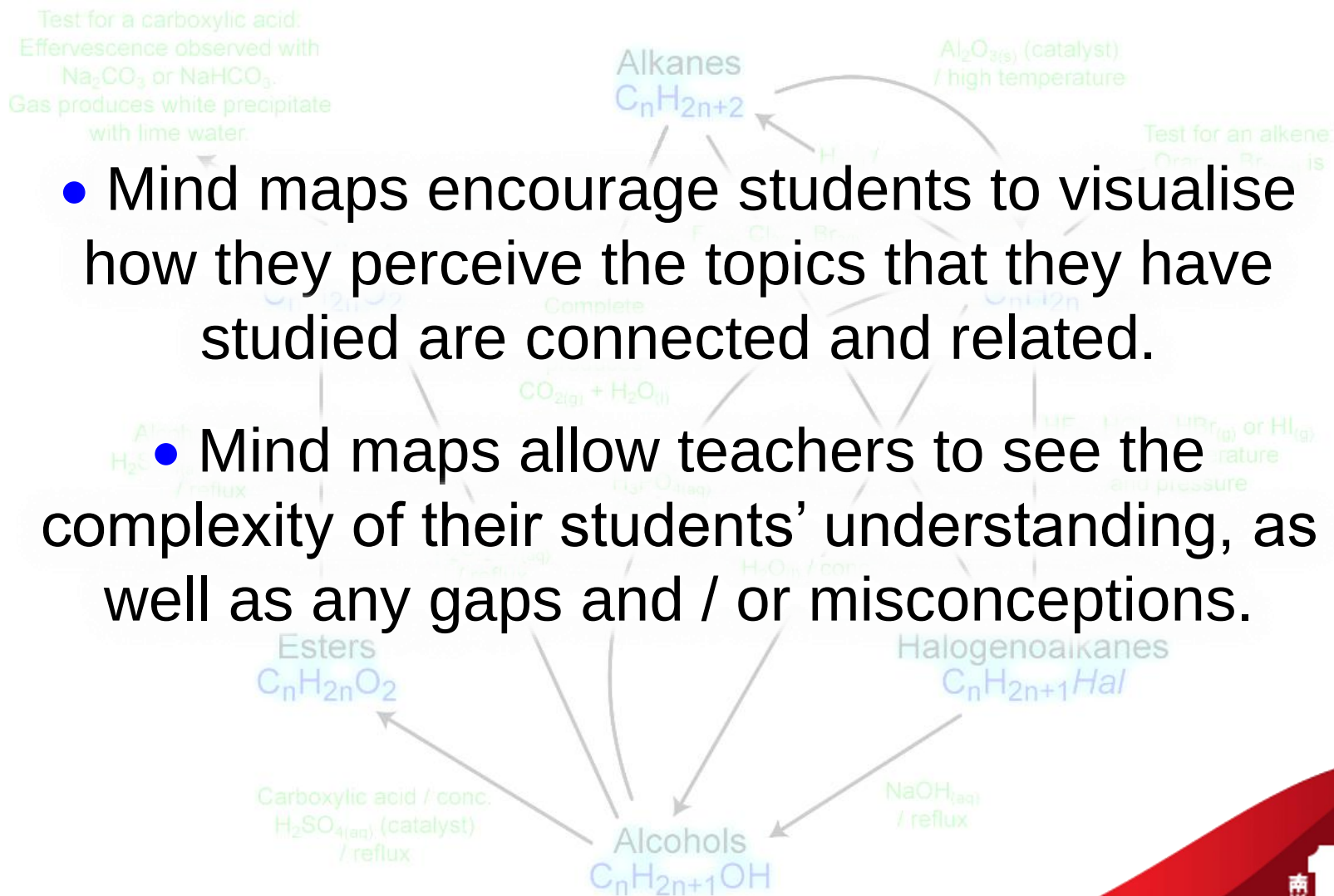
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26. Mind-maps



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26. Mind-maps



- Mind maps encourage students to visualise how they perceive the topics that they have studied are connected and related.
- Mind maps allow teachers to see the complexity of their students' understanding, as well as any gaps and / or misconceptions.

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27. In a Nutshell – Summary



Making Thinking Visible in Chemistry

27. In a Nutshell – Summary

- According to Johnstone (1991) the teaching and learning of Chemistry occurs across three domains; i) macroscopic ii) representational iii) sub-microscopic.
- It is not essential for the teaching and learning of topics in Chemistry to involve all three domains.
- The teaching of most topics begins with observations of macroscopic phenomena.
- Misconceptions tend to occur when students struggle to visualise and understand what is occurring at the sub-microscopic level.

Making Thinking Visible in Chemistry

27. In a Nutshell – Summary

- Both teachers and students of Chemistry should make their thinking visible to each other.
- Teachers should make their thoughts and explanations clear, using pedagogies that guide students to construct their own accurate understanding of the subject.
- Students should be given a range of opportunities to express their thinking in order for it to be scrutinised by their teachers and peers for inaccuracies and misconceptions.
- One way of helping Chemistry students improve their ability to visualise reactions at a molecular level is to encourage them to do some form of *art*.

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A faint, artistic illustration of a tea break. It features a white teacup filled with a light-colored liquid, a silver spoon resting on a white saucer, and a stack of three golden-brown, textured biscuits. The background is a soft, warm gradient.

Tea Break

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Part Three



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Teachers' Activity

1. Chose a topic in Chemistry.
2. What concerns do you have about teaching that topic?
3. What possible concerns do your students have about learning that topic ?
4. What possible misconceptions are associated with that topic?

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Teachers' Activity

- 5.** What visible thinking routines could help to:
- a)** Help teachers make their thinking visible in order to communicate ideas clearly to their students.
 - b)** Help students make their thinking visible in order to:
 - i)** Demonstrate a clear understanding of the topic.
 - i)** Highlight gaps in their learning and identify possible misconceptions.
- 6.** Please share your ideas.

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Miscellaneous Final Thoughts

- It is impossible to think outside the box, but you can make the box bigger, or even have several boxes.

- Curiosity is important in teaching and learning.

Curiosity resolution is satisfactory. The kind teacher is uninteresting, because they answer all of their students' questions for them, and do not challenge their students to think. Teachers should leave some gaps to stimulate curiosity. Students mirror their teacher – the teacher must be interested and curious themselves to avoid boredom and anxiety in their students.

- Science teachers can encourage their students to imagine and visualise things more easily by motivating their students to do art.

Making Thinking Visible in Chemistry



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Presentation on
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