Section 1

The curriculum in Wales is rapidly changing, and it is clear that a greater emphasis on developing pupils' problem-solving abilities is gathering pace. In 2014, all pupils from Year 2 to Year 9 sat national numerical reasoning tests for the first time, tests which explicitly assessed their ability to consider and select *independently* the *right* numeracy skills to use to solve real-life problems. The new GCSE Mathematics – Numeracy qualification, which will be taught from September 2015, is intended to contain assessment opportunities which are predominantly focused on numeracy *in context*, and therefore will also test this problem-solving ability. In a similar vein, the new specifications for GCSE English Language and GCSE Welsh Language from 2015 will include more demanding assessment criteria to assess reading skills, alongside more challenging texts and a range of question types. As noted by Qualifications Wales, the subject matter of GCSEs outlined in the specifications to be taught in Wales from September 2015 must, where appropriate, support opportunities to develop the 'Critical Thinking' and 'Problem-Solving' skills which are also an integral part of the Core of the Welsh Baccalaureate. As teachers, if we are to help students to progress through the curriculum in Wales and be successful, we must explicitly raise the profile of educating them to be proficient problem solvers.

Section 2

What is metacognition and how can its development in the classroom help pupils to improve at problem solving? Before we can answer this question, we need to take a further step back and consider the *cognitive* skills that might be used by any child or adult when faced with a challenging task. An individual might be asked to:

- draw a comparison;
- analyse implied meaning;
- test accuracy;
- consider the validity of competing viewpoints;
- draw inferences from tables and graphs…

…the list goes on!

As learners, we recognise over time that certain cognitive skills or strategies tend to be required, and tend to work rather effectively, in certain contexts. For example, when analysing poetry it is generally useful to be able to *test out symbolic interpretations of words and images*. Learners who understand this from an early stage tend to be able to analyse poetry in more depth and more detail. Those learners who approach poetry *already knowing* they will have to do this will be even more successful. In a different context, when confronted by a numeracy problem embedded in a prose description of an everyday situation, it is generally useful to abstract the figures and set them aside on a separate sheet and then double-check that no numbers have been 'left' unattended in the text. Learners who know to do this tend to get less confused by the combination of text and number and work through these reasoning problems more confidently.

Life outside of school (and increasingly within the curriculum as we have seen!) often presents us with problems and challenges that require us to mobilise and deploy a variety of cognitive skills and strategies simultaneously, or in new and unexpected ways. As learners, we are asked to move beyond the belief that for each task we encounter, there is a single appropriate skill that should be used. Although as teachers we may break subjects up into discrete skills, and in turn design schemes of work which isolate and develop skills as individual units, our ultimate aim is to produce students who can cope when things get more complicated and, crucially, can cope with this independently. Many of the challenges learners will increasingly face – in PISA, in numerical reasoning or in the new GCSE specifications – have been produced precisely to replicate this. Building the confidence and ability of learners so that they recognise the key components of a problem and identify the thinking skills that are likely to resolve it has never been so important.

Developing metacognition in students can help in this task. Metacognition can be defined as:

- 'the individual's own awareness and consideration of his or her cognitive processes' (Flavell, 1979);
- 'the ability to take out our thinking, and examine it, and put it back, rearranged if necessary' (Fisher, 1998);
- 'an awareness of the process of how an answer is found, what strategies and type of thought has gone on and the previous experiences that have been used' (Fisher, 1998).

At its simplest, metacognition is thinking about thinking. Its emergence can be described in the following example:

Pupil is struggling with a problem.

↓

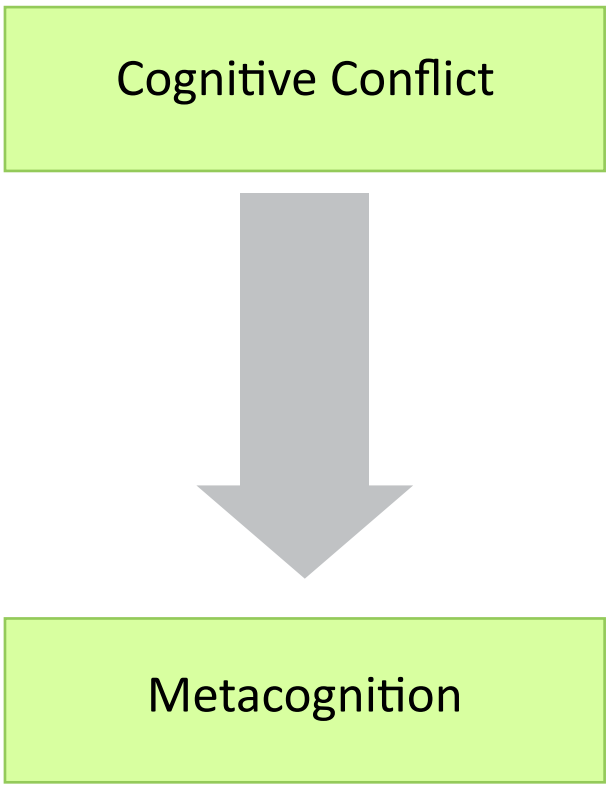
Pupil thinks 'I am struggling with this problem'.

↓

Pupil thinks 'I am struggling with this problem because I cannot identify the key words in the multiple-choice responses'.

↓

Pupil thinks 'I will make progress if I isolate the possible key words one by one and test them out against the text…'



Developing metacognition means:

- developing pupils' abilities to step outside of their thinking and reflect upon it;
- giving pupils the ability to monitor the strategies they use, consciously evaluating how successful these strategies are when facing a challenging task;
- giving pupils a vantage point from which they can review, evaluate and cross-combine the thinking skills, literacy skills and numeracy skills they have at their command;
- improving *resilience* in pupils, extending the amount of time they will spend grappling with a problem.

Pupils who are well practised in this are better able to deal with problems that they have not encountered previously, or which demand a variety of skills and strategies. They are better placed to take a step back, and monitor and evaluate their thinking while they are engaged in thinking about the problem itself.

How can metacognition be developed in the classroom?

As we have seen, pupils need to practise stepping outside of their own cognition, but this is no easy task! At the very least it implies a simultaneous development of oracy, as pupils develop a vocabulary to describe their thinking. They also require a steady supply of challenges and problems that are, by design, more open-ended, and which consciously demand a variety of cognitive strategies.

The following section will look at examples of developing metacognition in the classroom in various contexts. In a generic sense there are four main ways of developing metacognition:

1) Through continual and repeated emphasis on 'thinking' words in classroom discussion. For example, using words such as:
checking, considering, reconsidering, predicting, exploring, modelling, understanding, testing, guessing, etc.

Building in pupils the vocabulary required for metacognition.

2) By incorporating a repertoire of metacognitive questions. For example:

- *'How are you approaching this problem/ task?'*
- *'Where are the difficulties in this task and how will you try to overcome them?'*
- *'How have we resolved problems like this before?'*

Building in pupils the habit of viewing their thinking as a structure.

3) By planning opportunities for metacognitive plenary and review. For example:

- *'How did you do this thinking?'*
- *'What kind of thinking did you do?'*
- *'Was your thinking good? Why?'*
- *'How could you improve your thinking next time?'*

Building in pupils the ability to critically evaluate the strengths and weaknesses of their cognitive processes.

4) By modelling metacognition, providing a spoken commentary to whole group tasks:

- *'Now we are testing each statement to see if it is true...'*
- *'This idea is too complicated unless we put it in a diagram…'*

Allowing pupils to hear the language of metacognition working successfully in context.

Section 3

In this section we will take a look at some questions from real contexts. For each example, we will *reconstruct* the cognitive steps that might be taken to resolve them successfully.

Example 1

Context: PISA-style numeracy

A seal has to breathe even if it is asleep. Martin observed a seal for one hour. At the start of his observation the seal dived to the bottom of the sea and started to sleep. 8 minutes after his observation began, Martin noticed that the seal was back at the surface to take a breath. In 3 minutes it was back at the bottom of the sea again and the whole process started over in a very regular way.

Multiple choice:

After an hour was the seal…

a) On the surface?
b) On the seabed?
c) On its way up?
d) On its way down ?

To get the correct answer, (c), a number of slightly different routes could be followed, but they are all likely to be variations on the sequence of strategies set out below:

- identify the key numbers in the question (1 hour, 8 minutes, 3 minutes);
- note that the process is 'regular' (and can therefore be converted into a regular mathematical sequence);
- clarify the exact sequence of the seal's activity by carefully reading the text;
- create the mathematical solution (although many people confronted by this problem will also find it helpful to construct a diagram).

8 minutes to complete the sequence of dive – resurface – breathe.
The first 3 minutes in this sequence is spent diving to the bottom, whilst the next 5 minutes is spent resurfacing.
7 multiplied by 8 (minutes) is 56 (minutes), so after 56 minutes the seal has completed the sequence 7 times and is at the surface. The seal will take a further 3 minutes to dive to the bottom (59 minutes from the start) and therefore on the hour (60 minutes) will be returning to the surface.

Example 2

Context: PISA-style numeracy

In a mathematics class, the heights of all students were measured. The average height of boys was 160 cm, and the average height of girls was 150 cm. Rhian was the tallest girl – her height was 180 cm. Rhys was the shortest boy – his height was 130 cm.
Two students were absent from class that day, but they were in class the next day. Their heights were measured, and the averages were recalculated. Amazingly, the average height of the girls and the average height of the boys did not change.

Which of the following conclusions can be drawn from this information?

*Answer '**True**' or '**False**' for each conclusion.*

	True (Yes we know that)	*False (No we can't be sure of that)*
Both students are girls.		
One of the students is a boy and the other is a girl.		
Both students have the same height.		
The average height of all students did not change.		
Rhys is still the shortest.		

This is a deceptively complex problem! The key to testing whether the statements are true or false lies in first identifying clearly the conditions under which the averages could both remain the same. Once this had been done, it is relatively easy to test each statement in turn. However, for most, working out how the averages can remain constant will demand some thought! One possible way is to break it down by recreating some data that would 'work':

Day 1

	Boys	**Height**		**Girls**	**Height**	
Tallest	Tom			Rhian	180	
	Stephen			Gwen		
	Ryan			Masie		
	Ethan			Bethan		
	Ben			Alison		
Shortest	Rhys	130		Jane		
	Average	160		Average	150	

There is no need to fill in the 'missing' heights. By looking at the recreated data for Day 1 we can consider how two extra students for Day 2 might leave the averages as they are. Three possibilities can be teased out:

1. The two new pupils are one boy and one girl who coincidentally measure the average height 160cm and 150cm respectively.
2. The two new pupils are both girls and their heights average out at 150cm.
3. The two new pupils are both boys and their heights average out at 160 cm.

Other combinations (e.g. two girls of above average height) can be tested as well. Once we have satisfied ourselves that the three options above are the only ones available, we can easily test out the statements, and see that they are all 'False'.

Example 3

Context: PISA-style reading

Read the following extract :

What is puzzling is that while Calzaghe is regarded as a legend by anyone in the know (and anybody in Wales) he's hardly a household name. He shuns the celebrity circuit and when Marks and Spencer asked him to model underwear, he turned it down, partly because his girlfriend didn't like the idea. Nor is he one for gimmicky showmanship or stagey entrances. And, unusually for a boxer, he needs no entourage to big him up: he prefers to spend the hours before a fight alone with his iPod. In the past few years he has developed a fear of flying after a few turbulent flights and watching too many air-crash documentaries. At one point it got so bad he refused to get on a plane to New York at the last minute. He had checked in but when he discovered the plane wasn't a jumbo, he panicked. These days he takes medication to control the fear. Calzaghe recognises the need to 'sell himself' more, but deep down he feels slightly aggrieved that, given what he has achieved, he can't just be taken on his own merits. He is also quite shy. He blames it on a horrible period at school when he was bullied. He says, "In my third year I started getting picked on. I was quiet and one of the smallest boys in the year and they'd call me names and take the mickey. No one would talk to me and I just went into my shell. It really affected me, but I didn't tell my mum or dad. I bottled everything up and got really depressed."

Source: Celia Dodd reproduced from *The Times.*

Multiple choice

Which of these statements is not supported by the paragraph taken from 'The Boxer's Tale'?

a) Joe Calzaghe has a fear of flying.
b) Unlike most boxers, he prepares for fights on his own.
c) He was embarrassed by the idea of modelling underwear.
d) He had negative experiences at school.

The steps needed to identify the correct answer to this question are relatively straightforward. Having reread the passage to make sure we are clear about the impressions the author is trying to convey, we can skim through the text to find appropriate references to test out the statements above. Statements (a), (b) and (d) are relatively clear paraphrases of ideas in the text. To identify (c) as the correct answer we need to consider *how closely* it matches the comment about underwear modelling in the text. On reflection, the correspondence between statement and text is not a neat match: we are not told exactly *why* Calzaghe himself did not want to model underwear.

Example 4

Context: PISA-style reading

Read the following extract:

> *What would such a man make of Crufts? He would think he was in a madhouse, or the cathedral of a strange, dog-worshipping religion. A friend of mine was there and she reported that many people left clutching 'dog poo' bags, distributed free and bearing the logo of the Kennel Club. She was reminded of small children going home clutching party bags, after a hard afternoon of pass-the-parcel. Yet, while fully able to recognise the mad hilarity of it all, she also admitted to dithering over a £75 diamante collar for her border terrier.*

Source: Reproduced from *The Independent* (9 March 2004).

Multiple choice

Which of the following does this paragraph not emphasize?

a) That dog owners sometimes look a bit odd.
b) That dog owners may spend a lot of money on their pets.
c) That dog owners may lose a sense of perspective.
d) That dog owners like to copy each other.

Again, we need to look to see how closely the statements correspond to the references in the text, and identify the statement that is furthest from the text. This question is challenging because statement (a) *is* supported by the text, although it is quite a *broad* paraphrase. The same is true of (c). Statement (b) is clearly supported by the text and therefore can be dismissed quite quickly. Students need to clarify that although the text notes that a lot of the dog owners were carrying the same items, this does not really support the idea presented in (d), that they like to copy each other. This statement is not really paraphrasing an idea in the text, and is actually suggesting something quite different. It is not, therefore, describing something emphasized by this paragraph.

Example 5

Context: PISA-style scientific literacy

Study the following table:

The UK and China compared – facts and figures:

	UK	*China*
Population	***62 million (2011)***	***1.3 billion (1 billion = 1000 million) (2011)***
Unemployment rate	***7.8% (2011)***	***4.1% (2011)***
GDP per capita	***$38,974***	***$5,445 (2011)***
CO2 emissions (metric tonnes) per person	***7.7 (2011)***	***5.8 (2011)***
Energy use per person (kg of oil equivalent)	***3012 (2011)***	***1807 (2011)***
Investment in renewable energy	***$3.3bn (2010)***	***$54.4bn (2010)***
Life expectancy at birth (female)	***84 (2011)***	***75 (2011)***
Population growth (per year)	***0.8% (2011)***	***0.5% (2011)***

Source: World Bank

Multiple choice

Which statement best summarises the information provided in the table above?

a) China has a much greater total population than the UK, however the Chinese release less CO2 per person and invest more in renewable energy.

b) China has a slightly higher population than the UK, produces more CO2 per person but energy use per person is lower than the UK.

c) China has a much higher total population than the UK and whilst CO2 emissions per person are higher, energy use per person is lower that the UK.

d) China has a much higher total population than the UK and whilst CO2 emissions per person are lower, energy use per person is higher than the UK.

The challenge here lies firstly in understanding the data and in particular the units of measurement in the table. There is a lot of data to absorb, and not all of it is required to answer the question. The second challenge lies in the 'wordy' nature of the question statements themselves. The fact that they are all constructed in the same way initially makes it a challenge to disentangle them, although by studying them further we can see that they are all built on three propositions. It is then a more straightforward task to take each part of each statement in turn and test its validity. By doing this we can confirm that (a) is the correct answer.

Example 6

Context: PISA-style scientific literacy

Read the following extract:

A Non-Renewable Future ahead for China?
China Building More Power Plants

China is now building 550 coal fired power stations about two every week. Though there was no point in blaming China for rising global CO2 emission, Greenpeace director, John Sauven, reported that the average Chinese emits just 3.5 tonnes of CO2 per year, whereas Britons emit nearly 10 tonnes and Americans 20 tonnes. The west moved its manufacturing base to China knowing it was vastly more polluting than Japan, Europe or the US. No environmental conditions were attached to this move; in fact the only thing manufacturers were interested in was the price of labour.

Source: BBC News (2007)

Multiple choice (several correct answers)

Which of the following statements reflect the views put forward by the journalist in the passage above?

a) Chinese industry is more polluting than European industry.
b) Individually, US citizens release more CO2 than Chinese citizens.
c) The main motivation for locating industry in China is cheap labour.
d) China is largely responsible for climate change.

This question is challenging because we are not told how many of the four statements might be correct. We know we will have to check their validity even more precisely than before! The good news here is that the text is relatively short, although there is also a clear sense of authorial position and polemic regarding renewable energy and China. There is direct support for (a) in the third sentence, and (b) is supported by the figures in the second sentence. We can rework the fourth sentence to see that it corresponds fairly closely to the statement in (c). If these three statements are correct, we just need to test the validity of (d). There is not enough in the text itself to support (d) and, indeed, we can see that the author is beginning to build an argument that the West may well be 'responsible' for exacerbating climate change by moving its manufacturing base to China. This statement should be discarded from our answer.