Developing and assessing reasoning in Year 6

As one of the three aims of the national curriculum, it is important that all learners have the opportunity to develop their reasoning abilities throughout primary school. This resource has been created to support teachers in developing and assessing reasoning. Along with this introduction, there are a number of exemplified reasoning prompts, followed by a range of reasoning prompts that cover the UKS2 curriculum. Working at age-related expectations in Year 6 involves being able to **convince** and **justify** mathematically - and sometimes **prove** - a given response, statement or method *using the range of mathematical content in the primary curriculum.*

What is reasoning and why is it important?

Reasoning is made up of a number of ways of thinking – **innate thinking powers** – that all learners are able to engage in. When learners can actively engage these ways of thinking, they will learn more efficiently and remember more effectively because their learning builds logically on their previous understandings. This requires that they are given opportunities to actively make sense of concepts rather than being told what they need to know.

Understanding develops when we are able to make new deductions about a concept by making (better) sense of it. The deliberate process of convincing, justifying and proving mathematical ideas assists us in this and, when done collaboratively, can lead to improved shared understanding.

As well as being central to learning and developing understanding of mathematics, reasoning skills are also useful habits of mind that can be developed and applied to break into novel problems, solve them and to get ourselves 'unstuck' when encountering difficulties. The three main types of reasoning are described here. (The coloured items relate to innate thinking powers described by Mason et al 2010.)

Abductive reasoning, also known as **conjecturing**, is an active process of trying to make sense of information by looking for pattern or structure to explain what is going on. Based on experience or from comparing data (e.g. from specific examples created by learners), learners will conjecture their own ideas about the underlying relationships in a mathematical situation or problem.

Inductive reasoning is the process of **convincing** (first ourselves and then others) that should be expected to follow any conjecture. This might start with basic **describing**; saying what happened or how something was done – this is not yet inductive reasoning. However, once reasons start to be given (regardless of how correct or how coherent the argument is), we have the beginnings of inductive reasoning: **explaining**. At the next stage, **convincing**, the argument is more coherent and more likely to contain some correct mathematical reasons; the convincer will feel more confident about their ideas. The next step is **justifying**, which contains complete chains of reasoning based mainly on mathematically sound ideas. The argument may contain some unproven assumptions or could be logically correct but based on an incorrect generalisation.

Deductive reasoning provides a complete and coherent 'watertight' argument which is often based on correct generalisations and underlying mathematical structures and can be described as **proving** the conjecture. Although far from the only means, algebra can form an easily identifiable part of deductive reasoning because it can be used to demonstrate what happens in general, rather than just specific cases.

Generalising is making general statements (e.g. "This always/never happens when…" "If…then…") about an idea based on specific examples and the process of reasoning. The more thorough and logical the process of reasoning, the more accurate and useful the generalisations are likely to be

How do we develop the quality of reasoning?

Like any skill, practice is required to improve. Teaching will include activities that encourage learners to **analyse** mathematical ideas, make and justify their conjectures (or those of others) and articulate generalisations that deepen their understanding. Classroom dialogue is ideal for gathering and presenting differing views so that shared conclusions can be reached through discussion and clarification of each other's ideas. (*See the appendix for more detailed guidance.*)

Activities that encourage learners to **create** and contribute their own mathematical ideas have the additional benefit of providing formative assessment information and of motivating learners to be involved in the discussions. It is important that all learners' feel their ideas are welcomed so that reasoning is not seen as something that can only be done by some.

Learners' ability to reason and their ability to communicate their reasoning may differ, so part of developing reasoning is providing learners with models of our own 'thinking aloud' and the use of supportive reasoning stems. However, significant time needs to be spent helping learners to refine their own chains of reasoning and make accurate use of mathematical language. This is most effective when learners are leading the dialogue (with adult *facilitation* where needed) and they are able to engage in the shared construction of understanding.

Assessing reasoning

Assess the quality of learners' reasoning through using questions and prompts, during problem-solving activities and with rich tasks. For some learners, you will have plenty of evidence to draw on from whole-class activities. For others, you may decide to focus on learners working in a smaller group.

If a learner's reasoning is consistently limited to **describing** and **explaining** or if they **convince** with mostly weak or incorrect arguments (despite additional probing and scaffolding) they will benefit from further exploration of the content knowledge and more opportunities to reason about it collaboratively. Over time, as their understanding of the content develops, their reasoning may become more sophisticated and, increasingly, based on accepted generalisations.

The progression in reasoning below (and as described above) comes from the NRICH article "Reasoning: the Journey from Novice to Expert", which also suggests some reasoning stems and ideas for a self-assessment checklist for children to use to develop their own reasoning.

DESCRIBING > EXPLAINING > CONVINCING > JUSTIFYING > PROVING

If learners consistently **convince** and **justify** their ideas using age-appropriate content, they are likely to be achieving the reasoning and fluency aims of the national curriculum.

If learners can solve novel problems based on age-appropriate content, they are likely to be achieving all three aims of the national curriculum.

Additional resources alongside this document:

- a series of prompts and questions designed to promote and assess reasoning
- a set of rich problem-solving activities with teacher guidance and slides
- a grid relating innate thinking powers (including conjecturing, convincing and generalising) to questions that can promote them and actions (by learners) that may provide evidence

Appendix

Five practices for enhancing mathematical discussions

To facilitate learning, teachers need to engage with a question or task before using it with learners, in order to identify the key underpinning mathematical ideas and to **anticipate** learners' likely responses.

This will support teachers when **monitoring** learners' responses during exploration or when they are creating examples, in order to **select** and **sequence** which ones are presented for discussion.

In this way, teachers can ensure that learners have the opportunity to **make mathematical connections** to the key ideas for that content. (These five practices come from Stein et al. (2008))

Further guidance on developing effective dialogue

There is a place for all kinds of question in the maths classroom, depending on your purpose. In order to maximise the effectiveness of questions *for developing reasoning*:

- **Nurture a conjecturing atmosphere**, in which it is safe to experiment, try out ideas and make mistakes and in which the intention is for everyone to come to a shared understanding;
- **Plan questions** to focus on the key concepts that you want all pupils to understand and remember;
- **Allow time for thinking and developing responses**, including using well-planned "Think, pair, share" structures;
- In order to identify what all pupils think and understand, **listen carefully *to* responses** and invite additional or alternative perspectives; avoid listening ***for*** an expected response;
- **Encourage pupils to consider, evaluate, modify and challenge each other's ideas** by facilitating dialogue; avoid being the arbiter of what is mathematically correct – ultimately, you may be but pupils need to be active in their own learning.

References

Mason et al. (2010) *Thinking Mathematically*: Pearson

Stein et al. (2008) Orchestrating Productive Mathematical Discussions: Five Practices for Helping Teachers Move Beyond Show and Tell. *Mathematical Thinking and Learning* Vol.10, Issue 4 pp313-340: Taylor & Francis