ASKING QUESTIONS THAT ENCOURAGE INQUIRY-BASED LEARNING
How do we ask questions to develop scientific thinking and reasoning?

Introduction
This unit contains a selection of professional activities that are designed to help teachers to reflect on:

• characteristics of their questioning that encourage students to reflect, think and reason;
• ways in which teachers might encourage students to provide extended, thoughtful answers, without being afraid of making mistakes;
• the value of showing students what reasoning means by 'thinking aloud'.

The activities described below are given here as a 'menu' of suggestions to help the provider select and plan. They are presented in a logical order, building up knowledge and expertise.

Any planned professional development program should offer opportunities for teachers to try new pedagogies in the classroom and then report back and reflect on their experiences. Activity 4 is therefore essential in the program.

Activities
Activity A: Reflecting on the questions we ask.......................................................... 2
Activity B: What kinds of questions promote inquiry?.................................................... 4
Activity C: Observing a lesson ...................................................................................... 6
Activity D: Plan a lesson, teach it and reflect on the outcomes ..................................... 8
Activity E: Solve a problem, "thinking aloud"................................................................. 10

Acknowledgement:
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ACTIVITY A: REFLECT ON THE QUESTIONS WE ASK

Time needed: 15 minutes.

Give teachers time to discuss the following questions in pairs or small groups. Ask them to record their collective ideas on a copy of the handout. Then hold a plenary discussion to collect and share ideas. As teachers suggest different purposes, ask them to give particular examples.

Teachers ask many different types of questions and they serve many different purposes.
- What different types of questions are there?
- What different functions do these questions serve?
- Which types of questions do you use most frequently?
- What common mistakes do you tend to make when asking questions? What are their effects?

We ask questions for many possible reasons, including the following eight:
- to interest, engage and challenge;
- to assess prior knowledge and understanding;
- to stimulate recall, in order to create new understanding and meaning;
- to focus thinking on the most important concepts and issues;
- to help students extend their thinking from the factual to the analytical;
- to promote reasoning, problem solving, evaluation and the formation of hypotheses;
- to promote students’ thinking about the way they have learned;
- to help students to see connections.

The following is a list of some of the more common mistakes that teachers make:
- Asking too many trivial or irrelevant questions.
- Asking a question and answering it yourself.
- Simplifying the question when students don't immediately respond.
- Asking questions of only the most able or likeable students.
- Asking several questions at once.
- Asking only closed questions that allow one right/wrong possible answer.
- Asking 'guess what is in my head' questions, where you know the answer you want to hear and you ignore or reject answers that are different.
- Judging every student response with 'well done', 'nearly there' 'not quite'. 'Well done' can discourage alternative ideas being offered.
- Not giving students time to think or discuss before responding.
- Ignoring incorrect answers and moving on.
Handout 1. Thinking about why we ask questions

What different types of questions are there?

What different functions do your questions serve?

Which types of questions do you use most frequently?

What common mistakes do you make when asking questions?

<table>
<thead>
<tr>
<th>Common mistake</th>
<th>Unintended effect</th>
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What are the unintended effects of each of these mistakes?
ACTIVITY B: WHAT KINDS OF QUESTIONS PROMOTE INQUIRY?

Time needed: 20 minutes.

Give teachers time to discuss the following issues. Ask them to record their collective ideas on a copy of Handout 2 shown.

- What types of questions promote inquiry-based learning?
- Give some examples that you have recently used.
- Handout 3 describes some characteristics of effective questioning. Reflect on the implications of these ideas for your own practice.

Afterwards give them copies of Handout 3. This contains a summary of some research findings into questioning. This shows that effective questioning displays the five characteristics:

- The teacher plans questions that encourage thinking and reasoning.
- Everyone is included.
- Students are given time to think.
- The teacher avoids judging students’ responses.
- Students' responses are followed up in ways that encourage deeper thinking.

Invite teachers to discuss the research findings in small groups.

- Which of these principles do you usually implement in your own teaching?
- Which principles do you find it most difficult to implement? Why is this?
Handout 2. What kinds of questions promote inquiry-based learning?

What types of questions seem to encourage inquiry-based learning?

Give a few examples that you have recently used.

Now look at Handout 3.

This describes five principles for effective questioning. Reflect on the implications of these ideas for your own practice.

Handout 3. Five principles for effective questioning

1. Plan to see questions that encourage thinking and reasoning.
   - What effective questions are aligned with your learning goals? It is helpful to plan sequences of questions that build on and extend students’ thinking.

2. Ask questions in ways that include everyone.
   - Involve all students in the class in your questioning.
   - Make sure students understand the “why” and “how” of your questions.

3. Ask questions to sharpen and elaborate.
   - Challenge students to think more deeply.
   - Ask probing questions to encourage students to reflect on their own ideas and consider alternative perspectives.

4. Avoid judging students’ responses.
   - Encourage students to explore ideas and express their own opinions.
   - Praise students for their willingness to take risks and try new ideas.

5. Follow up students’ responses in ways that encourage deeper thinking.
   - Ask students to explain their thinking and reasoning.
   - Encourage students to build on and extend each other’s ideas.

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ACTIVITY C: OBSERVE AND ANALYSE A LESSON

Time needed: 30 minutes.

Work on the problem shown on Handout 4.

- Compare the two solutions. Which do you consider better and why?

Now watch the video clip of Gwen's lesson and consider the following questions:

- Which of the following principles can you see Gwen using in her lesson? Give examples.
  - Plan questions that encourage thinking and reasoning.
  - Ask questions in ways that include everyone.
  - Give students time to think.
  - Avoid judging students' responses.
  - Follow up students' responses in ways that encourage deeper thinking.
- What do you think students learned from the lesson?

- **Plan questions that encourage thinking and reasoning.**
  Gwen has carefully planned the lesson so that the focus is not on answers but on reasoning. She begins the lesson by emphasising that lesson will be focused on the quality of students' thinking, reasoning and explaining and on listening to each other. This message is reinforced throughout by her interactions with students:
  "Do you want to explain to me why that is fair?"; "How are you thinking of the journey? can you explain to me ..."); "How are you going to work out ...."; "What else is there that might help you? That's all I'm going to say. Keep thinking."

- **Ask questions in ways that include everyone.**
  Gwen has introduced a 'no hands up' rule, so that she can choose who will respond to her questions and so that students continue to think while responses are made. She tries to encourage a range of responses and asks students to comment on each others' responses.

- **Give students time to think.**
  Gwen gives students time to think individually before discussing, so that they all have something to share.

- **Avoid judging students' responses.**
  Gwen collects the students' initial ideas and writes these on the board. She asks follow-up questions for clarification ("Just explain a little bit more about that.") and thanks them for their contributions, but does not judge responses with 'Well done", or "That's not quite right."

- **Follow up students' responses in ways that encourage deeper thinking.**
  For example, Gwen invites students to elaborate: "Can you just say that again?"; asks students to think aloud: "Can you explain your thinking Alex?"; cues alternative responses: "Bethany, what do you think is best out of Hannah's suggestions?"; "Girls, can you see how that might help you? ... How might that help you?"
4. Observing a Lesson

Sharing petrol costs

Each day Dan’s mum drives him to school.

On the way, she picks up 3 of Dan’s friends, Chris, Ben and Anne.

Each afternoon, she returns by the same route and drops them off at their homes.

At the end of a term, the four students decide to pay a sum of 100 euros towards the cost of petrol.

How should they share out the cost?

Find some reasonable solutions and say which you think is best and why.

Two reasoned methods are shown below. Which do you consider better?

Method 1:

This is to share the cost in the proportion to the road distance people live from school:

2: 5: 8: 10. So:

Anne pays £8
Ben pays £20
Chris pays £32
Dan pays £40

Method 2:

Assume that, altogether, people will need to pay £10 per mile. Costs are shared out as follows:

<table>
<thead>
<tr>
<th></th>
<th>Anne</th>
<th>Ben</th>
<th>Chris</th>
<th>Dan</th>
</tr>
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<tbody>
<tr>
<td>Last 2 miles £20</td>
<td>£5</td>
<td>£5</td>
<td>£5</td>
<td>£5</td>
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<tr>
<td>Next 3 miles £30</td>
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Anne pays £5
Ben pays £15
Chris pays £30
Dan pays £50
ACTIVITY D: PLAN A LESSON, TEACH IT AND REFLECT ON THE OUTCOMES

Time needed:

• 15 minutes discussion before the lesson
• 1 hour for the lesson
• 15 minutes after the lesson

Choose a problem to try with your class.
Use the prompts on Handout 5 to plan a lesson that will promote thinking and reasoning.

• How will you organise the classroom and the resources?
• How will you introduce the questioning session?
• Which ground rules will you establish?
• What will be your first question?
• How will you give time for students to think before responding?
• Will you need to intervene at some point to refocus or discuss different strategies they are using?
• What questions will you use in plenary discussions during or towards the end of the lesson?

Because teachers will be focusing on the questions that they use and the way that the students answer those questions we suggest that they audio-record some whole class questioning lesson for discussion in Activity 5.

A sample lesson plan using the "Sharing Petrol Costs" problem is shown on Handout 6. This may be used as a model for teachers to follow.

After you have tried out your lesson with your own students, discuss the following issues:

• Which questions appeared to promote the most thoughtful and reasoned responses from students? Why was this?
• Which questions didn't work so well? Why was this?
• Which of the following four principles did you use? Give examples.
  o Plan questions that encourage thinking and reasoning.
  o Ask questions in ways that include everyone.
  o Give students time to think.
  o Avoid judging students’ responses.
  o Follow up students’ responses in ways that encourage deeper thinking.
• What will you do differently next time?
### 5. Planning for effective questioning

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### 6. A lesson plan on “Sharing Petrol Costs”

**Handout 6**

**Planning for effective questioning**

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**6. A lesson plan on “Sharing Petrol Costs”**

The following suggestions describe one possible approach to using the problems with students. This may take one or two lessons, depending on the class.

1. **Introduce the problem, and give time for individuals to think** 5 minutes

   Issue each student with just one of the three problems. Explain that in this lesson you are expecting everyone to think things through and to contribute:

   Today I am going to make sure you have plenty of time to think. I will give you a problem and I want you to think about how you got started with it for a few minutes. I will then ask for your ideas. There is more than one good way of doing this.

   No hands up, I will tell you when I want answers and who is to answer. Here’s the question I want you to think about...

   Explain how students are expected to start work on the problem:

   Read through the problem. How can we get started on this problem? What is known and what is unknown? What assumptions should we make? Remember I don’t want answers yet. I want you to know your ideas for getting started. You have exactly 3 minutes to think starting now.

2. **Collect initial ideas on the board** 5 minutes

   After the ‘thinking time’, pose the problem again then use the alternatives to questioning to generate discussion. (Record this part for later discussion if possible).

   Right let’s get started, what did you think about, Joe?

   Thanks for that explanation, Joe.

   Does anyone have any comments on Joe’s ideas?

   Yes I can see that, what else might we think about, Sarah?

   We’ve talked about three good ideas so far; does anyone have anything really different?

   Note that these questions are general and strategic. Do not comment on the specifics of the responses at this stage, even if students press you to tell them what is ‘best’ or who is ‘right’.

   Instead, simply record the ideas on the board, get the students to do this as they explain. That way the ideas will be there for the class to consider as they start to solve the problem. Remind them that although they have heard several strategies that will help them get started, that they should choose just one of them to start with. Explain what students should do when they are stuck:

   If you get stuck, think about the ways of tackling the problem we have talked about. Maybe you could try another one? Remember this lesson is about thinking and reasoning things out, so sit quietly and think about what you could do, then you could talk to a friend about what you are thinking. You are on your own, get going!

   Now set a target, reminding them to think about the reasons they make decisions as they work:

   Right, now I’m giving you twenty minutes to work on the problem by yourselves. Then I’m going to ask you some questions about what you have done and why you think the ideas you tried worked or didn’t work.

3. **Students work on the problem** 20 minutes

   Allow students time to engage with the problems. When they ask questions, ask them a question that offers strategic guidance rather than technical help. For example:

   Which way did you decide to use to start? Why?

   What have you found out? How did you do that?

   What didn’t work? Why? What might work?

   Think things out for yourself or between you – only call in the professional when you have tried everything else.

4. **Whole class discusses the approaches being used** 10 minutes

   When most students have made significant progress with the problem, ask the students about the way that they are working. (It may be helpful to record this part for later discussion).

   We are going to review progress so far. I don’t want anyone to talk strategies and ideas.

   I want to know what you have done so far. What have you tried that didn’t work?

   Why didn’t it work?

   What have you tried that seems to be successful? (It is a shame for thinking)

   Right let’s start with the first question – what did you try that didn’t work and why?

   When exploring the unsuccessful ideas remember to ask "What was the unhappy idea here? What would have made it work?" You are making sure that the students know its fine to make mistakes and take wrong turns when solving problems but it’s the successful ideas that you want, so after a few minutes ask for them:

   What assumptions made the petrol money sharing much easier?

   Can you justify your ideas?

   The idea is to provide models that will help students to make more progress on the problem. Make sure that the students know to the ideas given. Ask the next student to comment on how similar or different their idea is to those offered previously, rather than take isolated answers.

5. **Students have a second go at the problem** 10 minutes

   Encourage students to return to the problem and continue working on it using some of the ideas that have been shared.

6. **Whole class reports on their reasoning** 10 minutes

   Ask students to take turns at presenting their reasoning to the class.

   What ideas did you have that worked? Tell us why they worked.

   Focus on the thinking rather than the answers. Make sure they know there is no right answer to these problems. Ask questions such as:

   What was it about Sam’s idea that enabled her to solve the problem easily?

   What did Josh do that was particularly inventive or different?

   What ideas did Will have that you could see?
ACTIVITY E: SOLVE A PROBLEM, "THINKING ALOUD"

Time needed: 20 minutes.

Teachers usually present science and mathematics as though they are a set of tidy results and procedures. Students often don't recognise the invisible, messy processes that go on inside the heads of scientists. One reason why some students are reluctant to persist is that they do not recognise that it is perfectly natural to get stuck, make mistakes, backtrack and look for alternative strategies. It is therefore helpful for a teacher to model these processes by tackling a problem from start to finish, thinking aloud and involving the class by careful questioning.

In the professional development session, it is useful for teachers to think through this process by tackling a problem together, 'thinking aloud'.

Try working out an answer to the following problem, thinking aloud as you do so:

About how many dentists are there in your country?

Afterwards think what it would feel like, doing this with a class, not knowing the answer beforehand.

If you are working with a group of teachers, ask two volunteers to tackle the problem publicly, thinking aloud at the front of the room. The other teachers should take the role of the pupils and try to assist when asked to do so.

Afterwards, discuss other possible strategies that might help students realise the mental processes that scientists and mathematicians use every day. These may include, for example:

• Making a video of yourself and some colleagues solving a problem, while thinking aloud and discussing this with your class. We have included one such video on the resource.

• Students watching or reading biographies of mathematicians and scientists as they tell about their struggles and breakthroughs. See for example, Andrew Wiles' story on Youtube: http://video.google.com/videoplay?docid=8269328330690408516

• After working on a problem, reading solution attempts that have been produced by other students that reveal errors and the multiple trials and dead ends that have been encountered. Ask the students to work together to find, correct and comment on the 'errors in reasoning'. They should also comment on where the reasoning was good so that they may use these ideas again.
SUGGESTED FURTHER READING

Effective collection of questions for mathematical thinking

More effective questions for promoting mathematical thinking

Questioning to enable effective learning and assessment for learning

Questioning in the mathematics classroom, what really happens and what could happen?

Is questioning really important?

The questions that make pupils think mathematically