epiSTEMe Teaching Notes

Introductory Module

Contents

1. INTRODUCTION

The aims of the epiSTEMe project are to:

- get students more actively involved in mathematical and scientific thinking during lessons
- help them to achieve a deeper understanding and broader awareness of these subjects
- encourage them to aim high when making future choices about studying these subjects
- strengthen their learning in the key topics of fractions/proportionality and probability in mathematics, and forces and electricity in science
- raise the quality of teaching and learning through whole-class and small-group discussion

This Introductory Module is intended to help you achieve these aims, by raising the quality of whole-class and small group discussion and getting students more actively involved in mathematical and scientific thinking during lessons. A teaching approach that has been found to work well for both maths and science education is known as *dialogic teaching*: it is explained in the box below. This module will help you implement this approach not only throughout all the epiSTEMe modules, but throughout your teaching as a whole.

Dialogic teaching is about...

- achieving a *balance* between instructional, ‘authoritative’ teacher-talk and more open discussion with students

-using whole class discussion to reveal *what students think* and to stimulate their *reasoning*

- encouraging students to take *extended turns* in classroom discussions and *not evaluating* their responses immediately, but instead

- using students’ ideas in teaching, by building on and challenging them collectively

- making the most effective use of group work

Dialogic teaching treats whole-class discussion as an essential tool for helping both teachers and students appreciate what students understand, and do not understand, about a topic. It emphasises making connections between students’ existing knowledge and experiences, and the mathematical/scientific topic being studied. This is important for engaging students, helping them see the relevance of the subjects, and ensuring that any misconceptions are revealed and dealt with. Involving students in well-planned group activities has also been found to help develop their understanding and confidence in science and maths. In all discussions and tasks, the aim is to enable students’ *understanding* and *explanation* of ideas. Research has shown that students learn best if they are made accountable for understanding and explaining what they do, and not only for providing the correct answers. We will consider whole class dialogue and group work in turn: but they need to be co-ordinated, as parts of the same process.

> The classroom activities in this module should be carried out before the study of the epiSTEMe topic modules begins. It can take some time to establish a 'dialogic classroom', and so the sooner this process is begun the better.

2. SUSTAINING PRODUCTIVE WHOLE-CLASS DIALOGUE

Whole-class, teacher-led discussions can be extremely useful for developing students' understanding of science and mathematics. Especially important are discussions which allow students to reveal and question their existing ideas, including any confusions or misconceptions they may have, and begin to relate them to new scientific or mathematical explanations. Teachers also then gain a better understanding of what students know (and don't know) and so focus their teaching accordingly. However, opportunities for open, productive whole-class discussions about science or maths are often missed. Teachers may feel under pressure to 'get through' each topic in a crowded curriculum. They may find it difficult to manage the class and keep other students focused when allowing individual students to talk at length and 'think on their feet'. Teachers may also find it difficult to deal with incorrect ideas that students may offer. They may fear that challenging those ideas might be demoralising for the students or that sharing such ideas might mislead other students. These are all legitimate concerns, but many teachers have shown that they need not be obstacles to developing useful, productive dialogue. This module offers ideas and techniques for dealing with these very issues.

Research has shown that the most effective teachers do not only offer students opportunities to learn by hearing the teacher's authoritative voice on matters of science and mathematics, but also allow students to try to express their current state of understanding without feeling threatened or embarrassed. That is, they balance instructional, explanatory presentations (which can be called *authoritative* teacher-talk) with more open *dialogue*.

In **authoritative talk** the teacher:
- informs students about a subject through a prepared talk or lecture
- instructs students on how to carry out some task or procedure
- provides a demonstration of a phenomenon or procedure
- checks students' knowledge by asking for brief, factual answers to specific questions about subject content

In **whole-class dialogue**, the teacher:
- gives students opportunities to take long turns when talking
- avoids always judging students' contributions as either 'right' or 'wrong' but instead asks for clarifying questions or lets other students pose the questions or carry on the idea, delaying evaluating to promote conceptual discussion among students

- encourages students to ask questions about things they do not understand, both from the teacher and each other
- encourages students to share their thoughts, reveal their misunderstandings and make relevant comments and allows those to be collectively discussed
- expects students not just provide brief, factual answers but to justify their ideas with reasons
- gives air time for students' ideas irrespective of whether these are correct or incorrect if they are relevant for the topic at hand
- mediates the discussion, keeping it focused and helping students critically evaluate their and other students' ideas through asking well-timed clarifying questions or for justification or asking other students to respond.

Both authoritative talk and dialogue can be useful for helping students to learn: but students may need some encouragement and practice, over time, to get them to engage in dialogue. They will need to discover that hearing the views of their classmates on a topic can be interesting, and to develop confidence in expressing half-formed ideas in public. Teachers have found the strategies listed in the box below are often effective for encouraging students to contribute.

To promote whole-class dialogue it can be useful to:

- Ask "Why do you think that?" so that students have to justify their responses

- Ask not one, but several students for their ideas on the same topic/theme before moving on

- Hold back evaluations, demonstrations and explanations until the ideas of several students have been heard and critically discussed

- Make explicit the different (student) ideas that have been expressed and find/point out the difference between those

- Allow students to make extended responses, so they are able to think through their ideas as they speak

- Ask students to comment on each other's ideas (in a constructive way)

- Incorporate ideas and issues that students have raised to what you go on to say next

Below there are two examples of teachers engaged in a whole-class discussion at the beginning of a science lesson. In both cases, the topic is 'energy', and each example comes from the second of three lessons on this topic. Read these examples now, and consider what kind of use of talk is shown by each teacher is shown in the example. Then consider the comments provided.

EXAMPLE 1: WHOLE-CLASS DISCUSSION

Teacher: Do you remember the electric bell?
Students: Yes! [*in chorus*]
Teacher: OK! Did any of you notice, did any of you actually hold onto the bell after it had been working? What did you notice?
Suzanne: Vibration
Teacher: Well, the arm vibrated, yes. Sound. What else did you notice?
Tom: It was loud.
Teacher: That's not quite what I'm getting at.
Teacher: Remember the bell. There's the bell [*holding up a bell in front of the class*]. You did the experiment. If you held on to this bit here where the wires were [*indicating*], did you notice anything there?
Jason: There were sparks there.
Teacher: Heat, did you notice some heat?
Jason: There were sparks from there.
Teacher: There were?
Jason: Sparks.
Teacher: There were some sparks, yes. Let's just ignore the sparks a minute...some heat. There was a little bit of heat there with that one.

EXAMPLE 2: WHOLE-CLASS DISCUSSION

Teacher: Right, let me repeat what Kevin said. Hands down for a minute, you'll get arm ache. Kevin said a person in a hot place would have more energy than somebody in a cold place, because the sun makes Vitamin D. All right that's one idea. Let's hold that idea in our heads. Josh?
Josh: Um I actually think its the opposite of what Kevin said, because the sun's rays um, its just um that its colder, um so they'd be getting the same energy from the sun, but they wouldn't feel the same effect.
Teacher: That's a good point, so they'll get the same energy from the sun but they won't feel the same effect. Yes?
Emma: I'm not sure if this is right but um, say in a place like Africa, they have quite a few trees, and they kind of give us energy; but in this place like the Arctic, they don't have any trees.
Teacher: They don't have any trees, we've got lots of ideas coming out.
Cameron: It's to do with the atmosphere, in a hotter country there's a more dense atmosphere which takes up some of the um, energy, so they get as much as a thinner atmosphere in Antarctica or in the Arctic.
Teacher: OK so the atmosphere makes a difference. Right, let's see if we can take some of those ideas, and try and come up with an explanation?

Comments

In Example 1, the teacher asks students a series of questions about what they had noticed in the last lesson, and the students try to respond. However, it becomes clear that the teacher is not really interested in what they noticed. Only one possible answer could be right, and the teacher clearly judges all the answers offered as wrong. The teacher's questions are not designed to find out what the students noticed or learned in the last lesson, but just to generate a link between the last lesson and the current one. This is not a real whole-class dialogue, but a 'guessing game'. Such routines are used to focus students on what is relevant in the current task or help them remember previous lessons. However, They should not form the only kind of discussion in maths and science classrooms.

Example 2 shows a very different pattern of interaction. Teacher offers back a remark that one member of the class has made, and asks for views. A range of views is offered, with the students each making quite long contributions. Unlike in Example 1, the students talk more than the teacher. The views the students offer are noted, but not evaluated as right or wrong. Here the teacher genuinely opens up a 'dialogic space' in which student ideas can be expressed without immediate evaluation. The teacher has gained some understanding about what the students think, and can draw on these ideas when pursuing the topic as the lesson develops. The epiSTEMe topic modules aim to help teachers anticipate the kinds of ideas that students may come up with in different topics, including typical misconceptions. This should help teachers plan concrete ways of using those ideas for constructive and critical discussion with students, rather than leading students directly to the correct answer. Systematic teacher-mediated discussions of student-introduced ideas should help students advancing deeper new conceptual understandings rather than merely memorise correct answers.

This module is aimed both for teacher and student learning. As preparation, the **Activity 1** in this module is for only teachers themselves. It involves teachers recording one of their own lessons to hear how they actually talk in class. While many of us really dislike hearing our own voices recorded, teachers who have done this activity have found it immensely useful (and often surprising!) in identifying how they use talk and questions in whole-class discussions and thus how they might it change it in ways that helps student learning. This would also give you the opportunity to re-record a lesson later to see how the way you use talk in your classroom may have changed since implementing the epiSTEMe approach. Below are some comments from teachers that describe this experience.

> *I'm so much braver in doing nothing [since participating in the project]! I am so much less 'I need to get in there and I need to do something'. I'm actually getting quite good at standing back rather than just giving the answer and it's made me so much calmer, I love it! That bravery of standing back has been quite useful.*
> (Science teacher participating in the epiSTEMe project)

> *[What it distinctive about epiSTEMe is] getting children to take part and engage in their own learning, not just feeding them answers but really getting them to do some thinking. --- They have to learn they are not going to get the answers from me. --- It's been a very different approach, not telling them how to find the probability of something but letting*

them discover it. --- Instead of immediately stepping in to correct, my first response now is always why, why do you think that. And I think it's really made a difference and I do it in my other classes as well now so it's really changed my questioning style. --- [It has] given them more confidence, it's not just no you are wrong, yes you are right, but oh that's interesting. More confident in putting their hand up and suggesting something, and perhaps get the answer wrong. And articulate, explain, think more themselves of why they believe something, explore things. --- [It's important in a whole-class discussion] having a structure to it. You know how you are going to approach it but also being flexible if something comes up.

(Maths teacher participating in the epiSTEMe project)

Activity 1: How do you use whole-class talk?

(Teacher self-evaluation)

Objective

To monitor and evaluate your own strategies for sustaining productive whole-class talk.

Time

2 hours.

Resources

A voice recorder.

Activity

Identify a lesson when you are beginning a new topic. Include in your lesson plan an introductory discussion in which you can explore what students already know and understand (or do not understand) about the topic. (This could last up to about 10 minutes). Record this session. Listen to the recording.

Key ideas

When you listen back to it, consider the following questions:

1. How did your use of talk compare with the two teachers in the two examples in the Teachers' Notes?
2. How much time, proportionally, did you speak compared with the students?
3. What kinds of questions did you ask? Did you ask open questions as well as closed ones? Were your questions designed to make them reason and reflect on their understanding, or just to provide factual responses?
4. Did you use any of the 'Techniques for sustaining productive whole-class dialogue' listed on page 5?
5. Did you give students opportunities to make extended responses (or did you tend to interrupt or cut them off)?
6. Did you pick up ideas that students offered and weave them into the discussion?
7. How did students behave in this session? Did they seem willing to share ideas?
8. Did you find the discussion useful, regarding your teaching plans?
9. Finally, how happy are you with how the discussion went? Do you think you are making the most of such sessions?

3. PREPARING FOR GROUP WORK

Research has clearly shown that students' study of science and maths can be significantly improved by discussion and collaboration in small groups. However, research has also shown that simply asking students to go and work and talk together in groups will often not produce high quality discussion and learning. So we have the paradox that group work can be really useful for learning, but that it frequently is not. Why should this be? It may be that students don't normally see each other as learning partners, unless one of them already 'knows the answer'. When none of them knows the answer straight away, they often don't try to figure it out together but simply wait for the teacher to come and help. Sometimes students talk about the task but agree very quickly on some of the very first suggestions for the 'right answer' – or talk only about the procedures for doing a practical - without really thinking through the task together. At other times students may talk a great deal, but most of that talk is off-task. This raises two important questions. Do students understand *why* they are being asked to work together? And do they know *how* to work well together? It would be wrong to assume that the answer to both these questions is likely to be 'yes'.

Students need to develop the necessary discussion skills for group work to be productive, and teachers need to help them do so. Once you have helped them to work effectively together, you should start to see the benefits. A science teacher who worked with the epiSTEMe team commented as follows on the effects on her Year 7 class:

> *"...they again had to talk in groups to come up with definitions of thinking distance and braking distance - which they worked out brilliantly. We wrote on the board that thinking distance was 6m and braking distance was 6m, and then I asked them to predict what they would be with a speed of 40mph - everyone thought 12 and 12. So then we tried it - and of course found that braking distance was greater. But they were able to come up with really good explanations as to why thinking distance doubled, someone realised that braking distance quadrupled (I struggle to get my year 11s to notice that!) and someone else gave a really good explanation as to why braking distance more than doubled.*
>
> *We then went through different speeds and also conditions, and before each one they had to predict (after talking together!) what would happen to thinking and braking distance...Overall, we hardly did any writing in the booklets but it was a fantastic lesson and I was really chuffed with how well they were working and talking together and they REALLY enjoyed it."*

Use **Activity 2**: 'Preparing for effective group work' to explore your students' ideas about the purposes and functions of talk in the classroom and to get them started on improving their own use of talk for learning.

Activity 2: Preparing for effective group work

Objective

To help students reflect on the purposes and functions of group work and evaluate their own use of talk for learning.

Time

15 minutes.

Resources

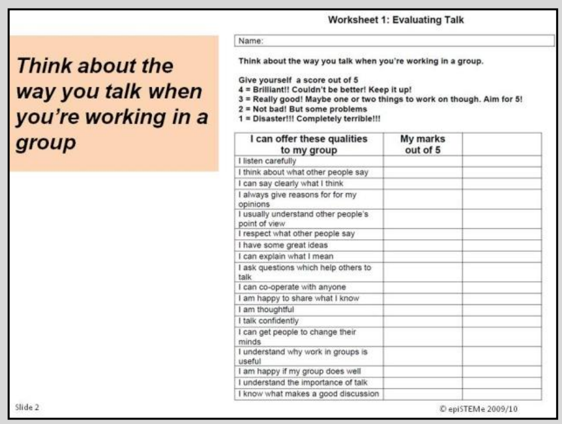
Slide 1: ‘Think about the way you talk when you’re working in a group’. See also the Notes Section in Slide 1; Worksheet 1: ‘Evaluating talk’ for students.

Activity

Whole-class activity

Explain the objective of Activity 1. Ask students ‘Who do teachers ask you to work together in groups?’ Ask them if/why they think talk in science/maths classrooms is useful or not. The questions on the slide (and in the slide notes) are useful for stimulating the discussion.

Allow students time to make extended responses to the questions. Do not evaluate their answers yourself, but ask if other students agree/disagree with what anyone says (and ask for explicit reasons why).



Worksheet 1: Evaluating Talk

Name:

Think about the way you talk when you're working in a group.

Give yourself a score out of 5
4 = Brilliant!! Couldn't be better! Keep it up!
3 = Really good! Maybe one or two things to work on though. Aim for 5!
2 = Not bad! But some problems
1 = Disaster!!! Completely terrible!!!

I can offer these qualities to my group	My marks out of 5	
I listen carefully		
I think about what other people say		
I can say clearly what I think		
I always give reasons for for my opinions		
I usually understand other people's point of view		
I respect what other people say		
I have some great ideas		
I can explain what I mean		
I ask questions which help others to talk		
I can co-operate with anyone		
I am happy to share what I know		
I am thoughtful		
I talk confidently		
I can get people to change their minds		
I understand why work in groups is useful		
I am happy if my group does well		
I understand the importance of talk		
I know what makes a good discussion		

Individual work

Hand out Worksheet 1: ‘Evaluating Talk’. Ask each student to fill in their responses. Collect all the students’ sheets. Completing this exercise will be helpful to students, but you also should find their responses informative.

4. ESTABLISHING GROUND RULES FOR *EXPLORATORY TALK*

It is critically important for the success of the epiSTEMe programme that students are able to work well together in groups. It has been found that without agreeing some shared 'ground rules' for working together, students are unlikely to co-operate effectively.

The kind of discussion we want students to engage in groups is known as Exploratory Talk. It happens when students do the things described in the box below. Essentially, Exploratory Talk means working and talking in the ways an effective team of scientists or mathematicians would use to solve a problem.

In Exploratory Talk:

- All relevant information is shared amongst the group
- Assertions and opinions are backed up by reasons
- Suggestions and opinions can be challenged and questioned, but in a respectful way
- Alternative options are considered before any decision is made
- Everyone in the group should be encouraged to speak by the other members
- The group works towards reaching agreement
- The group accepts collective responsibility for decisions made and actions taken because of those decisions

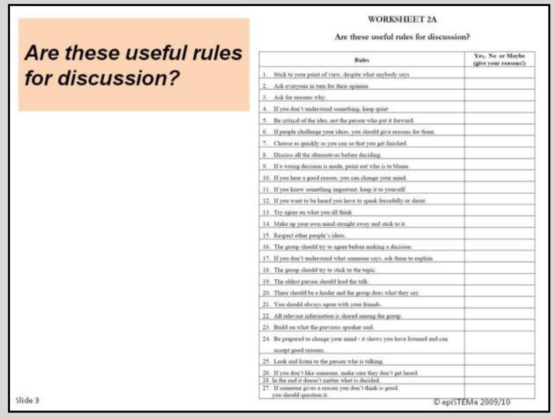
What is needed, then, is for students to agree on a set of 'ground rules' for working together which will generate lots of Exploratory Talk. A suitable set of ground rules shown in the box below.

It is important that members of a class feel ownership of and commitment to their set of ground rules. **Activity 4** should enable you to create a suitable set of ground rules which you can propose for adoption by the class. Ideally, your class's ground rules should embody all the features of Exploratory Talk listed in the box above but expressed more informally, as they are in the box to the right.

Ground rules for Exploratory Talk
In group work we should...

- ask each other what we think
- make sure everyone's voice is heard
- ask for reasons, and give them
- share relevant information
- treat everyone's ideas as worthwhile
- question anything we think is wrong
- try to reach agreement
- trust each other and act as a team!

Activity 3: Exploring ground rules for talk



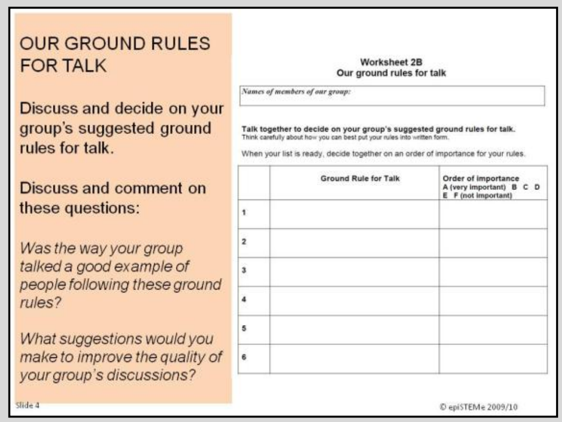
Objectives

To help students understand the idea of 'ground rules' for talk and how this applies to their group discussions.

To enable you to gather resources for constructing a set of ground rules for talk which will be adopted by your class (in Activity 4).

Time

20 minutes.



Resources

Slide 3: 'Are these useful rules for discussion?' and Slide 4: 'Our ground rules for talk'.

Worksheet 2A: 'Are these useful rules for discussion?' and 2B: 'Our ground rules for talk' for students; a flipchart.

Activity

Whole-class activity

Refer back to the previous activity and what the class discussed about talking and working together. Briefly introduce the concept of 'ground rules', meaning the implicit, informal rules that people follow in particular types of social situation. Explain that the purpose of this activity is to check that everyone in the class agrees on what rules we should use when working in a group, to ensure the most productive discussion takes place. Explain that problems arise when people are not using the same ground rules. Ask them 'Do you think you all use the same ground rules in group discussions?' Offer an example of a useful ground rule, such as: 'Everyone's views should be heard before a decision is made'. Ask members of the class to suggest other rules they think would be useful. You might record the suggestions on a flipchart or IWB.

Small group work

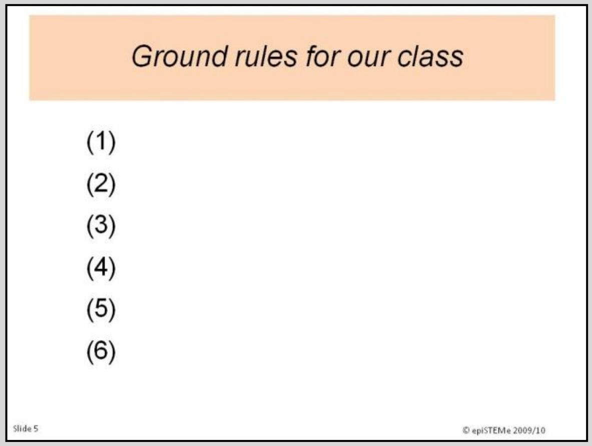
Organise students in groups of 3 or 4. Provide each group of pupils with one copy of Worksheet **2A:'Are these useful rules for discussion?'** Give them about 10 minutes to carry out this activity. Then hand out **Worksheet 2B: 'Our Ground Rules for Talk'.** Refer back to the potential ground rules that students have considered and ask the groups to create and decide on their own 'ground rules for talk', and then write them down on **Worksheet 2B**. Collect these in.

Activity 4: Establishing ground rules for exploratory talk

Objectives

To establish some ground rules talking effectively in groups, based on students' proposals in Activity 3 and on the principles of Exploratory Talk.

To get the class to agree on a set of ground rules.



Time

10 minutes *(in the lesson after Activity 3).*

Resources

Slide 5: 'Ground rules for our class'; the students' completed Worksheets 2B from Activity 3.

Activity

Before the lesson

Drawing on what students have written on Worksheet 2B in Activity 3, and the list of features of Exploratory Talk listed on page 10 of this booklet, produce a set of 6 (maximum) 'Ground rules for group work in science/maths'. While it is important to try and draw on what groups wrote on Worksheet 2B, it is essential that your proposed rules closely match the principles of Exploratory Talk.

Whole-class activity

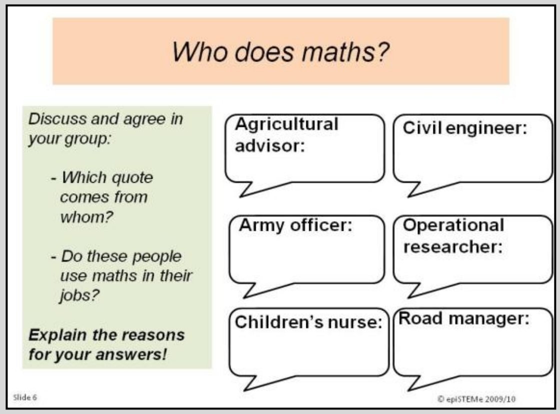
Propose this list for adoption by the class at the beginning of the next lesson. You could ask the class if they think your list misses out any essential features that they came up with in their own discussions, and include them too if appropriate.

Once adopted, the list of ground rules should be **prominently displayed on the wall**, for future reference.

5. PRACTISING GROUP WORK

Once the ground rules have been established, it will be important that students have some opportunity to develop their group work skills through practice. The four activities below (two related to maths, and two to science) have been designed for that purpose.

Activity 5a (Maths): Who does maths?



Objectives

To allow students to practise using the ground rules for talking and working together.

To enable students to broaden their understanding of the practical relevance of maths.

Time

40 minutes.

Resources

Slide 6: 'Who does maths?'; Worksheet 3M: 'Who does maths?'; Quote cards.

Activity

Whole-class activity

Organise the class into groups of 3 or 4. Hand out **Worksheet 3M: 'Who does maths?'** with sets of job and numbered quote cards (one set per group). Explain that the group work task is to try to decide, as a group, the answers to each of the questions on the sheet (in the order they appear). Display the ground rules of the class for group talk on the whiteboard and remind the students of them. The group should make sure that they can *provide reasons* for their eventual decisions, which they can share later with the whole class. You should say that it doesn't matter if they provide answers to all the questions: the important thing is that they talk properly about each one, and try to agree an answer.

Small-group work
The groups then should have 15 minutes to carry out the activity. Close to the finish time, remind them that they should have agreed reasons for their answers to each question. They should fill in Worksheet 3M as a group.

Whole-class activity
Select a few completed sheets, and get feedback from the groups about how their discussion had gone. Did they find the task difficult? Did they find it helped to talk about it? Did they follow the 'ground rules'? Did all members of a group agree with the decisions (and if not, why not).

If there had been little productive discussion, you could go through the ground rules one by one with the class, asking students to report to what extent they think they had followed each one of them (even "vote"). Think about the kinds of questions you should ask in the in whole-class discussion and what kind of feedback you give. If there is time, get the class to discuss the answers provided by the different groups.

Activity 5b (Science): Are nurses scientists?

Objectives

To allow students to practise using the ground rules to talk and work together.

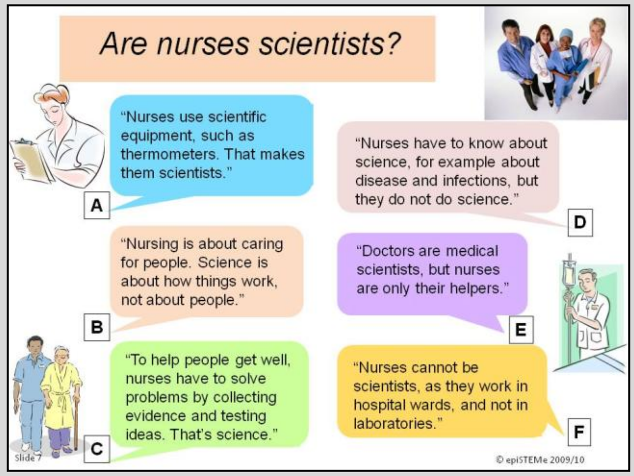
To enable students to broaden their understanding of the practical relevance of science.

Time

40 minutes.

Resources

Slide 7: 'Are nurses scientists?'; Worksheet 3S: 'Are nurses scientists?'.



Activity

Whole-class activity

Organise the class into groups of 3 or 4. Hand out **Worksheet 3S: 'Are nurses scientists?'.** Explain that the group work task is to try to decide, as a group, which of the statements about nurses the group agrees with. Display the ground rules of the class for group talk on the whiteboard and remind the students of them. The group should make sure that they can *provide reasons* for their decisions, which they can share later with the whole class. You should say that it doesn't matter if they provide answers to all the statements: the important thing is that they talk properly about each, and try to agree an answer.

Small-group work

The groups then should have 15 minutes to carry out the activity. Close to the finish time, remind them that they should have agreed reasons for their decisions about the statements. They should also fill in Worksheet 3S, listing their main reasons for whether or not they agree with each statement.]

Whole-class activity

Get feedback from the groups about how their discussion had gone. Did they find the task difficult? Did they find it helped to talk about it? Did they follow the 'ground rules'? Did all members of a group agree with the decisions? If not, why not?

If there had been little productive discussion, you could go through the ground rules one by one with the class, asking students to report to what extent they think they had followed each one of them (even "vote"). Think about the kinds of questions you should ask in the in whole-class discussion and what kind of feedback you give. If there is time, get the class to discuss the answers provided by the different groups.

6. INTERVENING EFFECTIVELY IN SMALL GROUPS

Having agreed suitable ground rules, group work is most likely to be effective if…

- the tasks are well suited to collaborative activity, are not too easy and are not too hard (All the epiSTEMe science and maths activities have been designed on this basis)
- students are given enough time to get really involved in discussion without premature teacher intervention
- students are asked to evaluate the quality of their discussion, and to feed back from their discussions into whole-class discussion

In supporting productive small-group discussions, what teachers *don't* do is sometimes as important as what they *do*. When students are working in groups, you might feel tempted to intervene soon after they begin to ensure that they are on task, or in case they are struggling. However, it is more productive to let students first try to tackle the task together for a while without teacher intervention.

To ensure that students try and do this rather than expect immediate teacher help, a helpful strategy is to set an additional 'ground rule' that *a group should try to come to an agreement before they can ask for help from the teacher*, even if this is only agreeing on the question to ask. In this way, students know they need to talk to each other first.

Of course, sometimes you will see that a group is really not getting anywhere, and that they need some help. When you do intervene, it is a good idea to *address the whole group*, rather than any individual student within it, to reinforce the message that they are meant to be working together. The box on the right lists some questions you might ask.

Questions to small groups...

- *"What have you agreed on so far?"*
- *"Did you all agree?"*
- If not, *"Why not?"*
- *"Can you give me reasons for your decision?"*
- *"Why do you think that?"*
- *"Did you consider other solutions?"*
- "*Tell me what you think the task is asking you to do"*

In the examples below, the teachers use several strategies to support a group discussion. In Example 3, when the students are actively talking, the teacher *avoids interrupting* the discussion and instead joins in as a listener, thereby indicating that the discussion is interesting and that listening to the other students is important. Through listening to students he also *signals* that their contributions are all valid and thereby encourages students to take extended turns. He draws in those students who are not engaging actively, thereby *modelling* the ground rule of asking everyone what they think and ensuring everyone is heard, while at the same time modelling the kinds of questions that the students could ask each other during the discussion. He gives *encouragement* and *focuses the students on relevant points*. He also assists their discussion through *rephrasing student contributions*.

EXAMPLE 3: INTERVENING IN GROUPS

The teacher joins a small group that is working on a discussion task about floating and sinking. He kneels down to be on face level with the students but doesn't say anything. He just signals without words that he is listening and interested in what the students are saying. After several student turns he addresses the group members who have not yet said anything:

"What do you guys think?"

The other students contribute. Then the teacher also comments:

"That's a good point! Did you hear that? Big ships like he Queen Mary don't sink. Even though they've got big engines, made from metal, they atre very heavy."

A student suggests an explanation. The teacher asks the other students:

"OK what do you guys think? So Josh is saying that the water gets in and …"

EXAMPLE 4: INTERVENING IN GROUPS

The teacher joins another group working on floating and sinking, addressing the whole group, he asks:

"OK guys, where have you got to?"

Several students offer extended contributions and explanations. After a few comments the teacher joins in:

"Guys, can I just comment just there, you guys were all thinking, all three of you. You were all thinking independently just then, you all had different ideas. But Jamie said something that might have been worth talking about. Then Sam said something which might be worth talking about. And then Michael said something that might be worth talking about. If you take turns and you can feed off each other's ideas. Go on!"

Before leaving the group he reminds them they need to try to reach an agreement.

In Example 4 the teacher gets the discussion going again through asking all students to share their views. He points out to them that they need to listen to each other's ideas and compare their ideas. Through *avoiding premature assessment* of student contributions he enables an exploration of a range of ideas, rather than encouraging students just to hunt for the right answer. He also explicitly and implicitly *reminds the students of their ground rules* for talk.

In Example 5 below, the teacher focuses the struggling students on the task and asks them to think together about what the task is asking them to do rather than telling them. She then assists their discussion through suggesting they think about what they already know that might help them solve the task, thus modelling a strategy that can be generally useful. She also models a further strategy through suggesting the students have a go at estimating the probabilities.

EXAMPLE 5: INTERVENING IN GROUPS

The group are working on a probability task. The teacher joins the group and addresses the whole group.

"How are you doing boys?"

The students tell her they are a bit stuck on how to work it out. Teacher comments:

"OK. What are we trying to work out? Do you understand what we need to work out?"

Together the students manage to establish what the task is asking them to do but still cannot solve it. The teacher asks:

"OK, so do you have any information that might help you?"

The students tell her the task tells them which result is the most common and which the least common one. The teacher asks a new question:

"OK, so does that help you? If you had to estimate the probability, how do you think you would do it?"

A student suggests the particular result he thinks would have a low probability. Teacher asks again:

"Why do you think it would be low?"

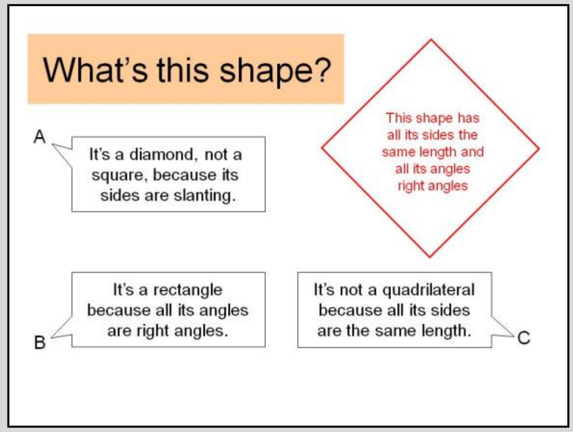
The teacher listens to a few more student comments, then asks them if they think they can now solve the task together. She then leaves the group without working through until the answer with them.

Through *asking for reasons* ('why do you think that?') she seeks to ensure that focus remains on *explanation and meaning*, on student understanding, not only 'correct answers'. In this example the teacher offers the students strategies for starting to work on the task together, rather than working through the steps of the task with the students. She does not 'take over' and perform the difficult bits for them.

In summary then, effective group work is most likely to happen if you:

- establish some ground rules for talk
- set students activities well-designed for group work
- intervene only when necessary, and do not take over
- get students to report back on their discussion to whole-class sessions.

Activity 6a (Maths): What's this shape?

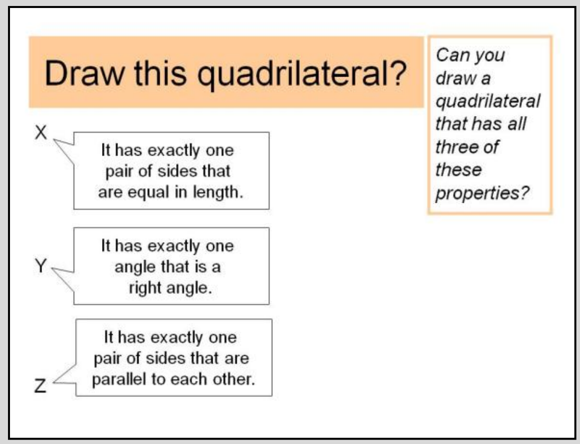


Objectives

To help students learn about the value of talk for mathematical thinking and learning.

To enable the teacher to explore productive ways of supporting small group and whole-class discussion.

('What's this shape?' is the main version of the activity. 'Can you draw this quadrilateral?' is a more difficult version which can be used either as a follow-on activity or as an alternative for high-attaining groups.)



Time

40 minutes.

Resources

Slide 8: 'What's this shape?' and/or Slide 8: 'Draw this quadrilateral?; Worksheet 4M: and/or 4M+ for students.

Activity

Whole-class activity

Organise the class into groups of 3 or 4. Hand out **Worksheet 4M: 'What's this shape?'**.

Alternatively, use **Worksheet 4M+: 'Can you draw this quadrilateral?'** if you judge 'What's this shape?' to be too easy for your class.

If using Worksheet 4M: Explain that the group work task is to try to decide, as a group, what mathematical terms can be applied to the shape shown and described at the top right. In particular, each group needs to decide which, if any, of the boxed statements about the shape are mathematically correct. Remind the students of the ground rules of the class (and have them visible in class). Each of the statements suggests a mathematical word to describe the shape, and gives a reason for choosing that word. For each statement, the group should discuss (and eventually decide) not only whether or not the choice of word is mathematically correct, but if the reason offered for using it is a sound one. They should make sure that everyone in the group has a chance to put forward their point of view, and that different points of view are properly discussed.

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If a group thinks that it can come up with a better statement, it should do that. Ask the students to make sure that this statement not only suggests what mathematical term or terms can be applied to the shape but includes a reason (or reasons) for that suggestion.

On the back of the Worksheet 4M there is a grid for recording the decisions that the group makes about each statement.

If using Worksheet 4M+: For high-attaining groups you may choose to use this version of the task, either as a follow-on to the main task or as a substitute for it. Explain that the group work task is to try to decide, as a group, if it is possible to draw a quadrilateral that has all the properties suggested in the three statements. They should do so through trying to draw the shape. If they suggest that it cannot be done, they should agree on reasons for this. They should make sure that everyone in the group has a chance to put forward their point of view, and that different points of view are properly discussed. If a group is finished early, a further extension would be for them to make up their own problem of this type.

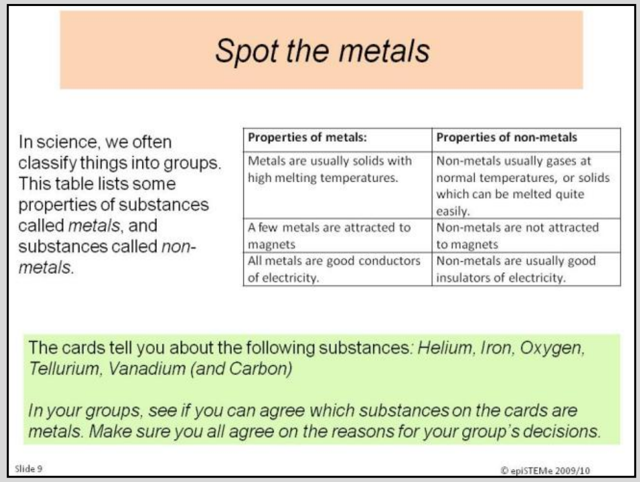
Small-group work

The groups then should have 10 to 15 minutes to carry out the activity. Close to the finish time, remind them that they should have agreed reasons for their answers to each statement. Ask students to record their views on the Worksheet 4M/4M+.

Whole-class activity

Get feedback from the groups about their conclusions. Ask groups to provide their *reasons* and allow for extended responses. Hold back from evaluation of student responses at this stage until the ideas of several students have been heard. Instead invite students to comment on each other's ideas. Try to incorporate in your own contributions ideas that students have raised.

Activity 6b (Science): Spot the metals



Objectives

To allow students to practise using the ground rules to reason together about a scientific topic

To help students learn about the properties of metals and non-metals.

Time

40 minutes.

Resources

Slide 9: 'Spot the metal'; Element cards as supplied (5 element cards with a 6th element card (Carbon) to be used as an extension); Worksheet 4S: 'Spot the metal'.

Activity

Whole class activity

Organise the class into groups of 3 or 4. Hand out the cards for the activity (one set per group) and **Worksheet 4S: 'Spot the metal'**. Use your own judgement on whether or not to include the sixth element card (Carbon), which will make the activity more demanding. Explain that the group work task is to try to decide, as a group, whether or not the substance named on each of the cards is a *metal*. They should discuss each one in turn, hearing everyone's views, and then put the card into one of two piles: 'metal' and 'non-metal'. You and the groups will notice that the first elements are fairly straightforward to group but the task gets increasingly challenging as the group moves through the cards. The group should make sure that they can *provide reasons* for their eventual decisions, which they can share later with the whole class. Importantly, tell the groups that you will expect to be able to ask *any member* of the group to be able to explain the decisions in the later whole-class session (that is, they cannot pick a spokesperson – you will decide who to ask. This is intended to ensure that all group members take full part in the deliberations).

Small-group work

The groups then should have 15 minutes to carry out the activity. Close to the finish time, remind them that they should have agreed reasons for putting each card in the appropriate pile. They should also record their main reasons for whether or not the substances are metals on Worksheet 4S.

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Whole-class activity

Select cards from the set, and choose a member of each group to say whether or not they decided it was a metal. Collect a range of views without evaluating them as ‘right’ or ‘wrong’. Be sure to ask for their *reasons* for deciding; and also ask if all members of a group agreed with the decisions (and if not, why not). Give the representative of each group long enough to explain properly, and prompt them if necessary. You may want to end this session with an ‘authoritative’ explanation of which of the substances are metals, and about the classification system itself (see Key Ideas below).

Key ideas

The substances are all elements, as the distinction between metals and non-metals strictly only applies to elements. Of course, the metal/non-metal classification is an oversimplification. Tellurium does not fit in the classification scheme of metal or non-metal, and you should explain that to the students: but it also worth pointing out to them that nevertheless the distinction is useful.

Acknowledgements

The information in Activity 5a ('Who does maths?') was extracted and adapted from:
http://www.mathscareers.org.uk/post_16/career_profiles.cfm

Thanks to Professor Phil Scott, University of Leeds, for the transcript in Example 1 on p. 4.

APPENDIX 1: epiSTEMe

The epiSTEMe project [Effecting Principled Improvement in STEM Education] is part of a national programme of research that aims to strengthen understanding of ways to increase young people's achievement in physical science and mathematics, and their participation in courses in these areas. Drawing on relevant theory and earlier research, the epiSTEMe project has developed a principled model of curriculum and pedagogy designed to enhance engagement and learning during a particularly influential phase in young people's development: the first year of secondary education. This module on Probability is one of four topic-specific modules that have been developed to operationalise that model and support its classroom implementation.

The teaching model

The epiSTEMe teaching model builds on current thinking in the field and on promising exemplars that have been extensively researched. These suggest that students' learning and engagement can be enhanced through classroom activity organised around carefully crafted problem situations designed to develop key disciplinary ideas. These situations are posed in ways that appeal to students' wider life experience, and draw them more deeply into mathematical and scientific thinking. Such an approach is intended not just to help students master challenging new ways of thinking, but also to help them develop a more positive identity in relation to mathematics and science.

An important feature of the teaching model is the way in which it makes explicit links between mathematics and science. Within mathematics modules, the primary rationale for this is that science represents a major area where an unusually wide range of mathematics is applied, often for a variety of purposes. Within science modules, the primary rationale is that understanding of scientific ideas is deepened by moving from expressing them in qualitative terms to representing them mathematically.

The teaching model also emphasises the contribution of dialogic processes in which students are encouraged to consider and debate different ways of reasoning about situations. These dialogic processes are designed to take place in the course of joint activity and collective reflection at two levels of classroom activity: student-led (and teacher-supported) collaborative activity within small groups, and teacher-led (and student-interactive) whole class activity. Because of the importance of developing dialogic processes that support effective learning, these processes are the focus of a separate Introductory Module, which is additional to the four topic-specific modules.

The design of the topic-specific modules

The function of all four topic-specific modules is to provide examples of concrete teaching sequences that incorporate classroom tasks that reflect the teaching model. The tasks will, in particular, support dialogic processes and student learning from these tasks will be supported by these processes.

First, each module has been designed to cover those aspects of the topic prescribed for the start of the Key Stage 3 curriculum, and to do so in a way that is suited to students across a wide range of achievement levels. Taking account of available theory and research on the development of students' thinking in the topic, the module 'fills out' the official prescriptions in ways intended to build strong conceptual foundations for the topic. This includes providing means of deconstructing common misconceptions related to the topic.

In this way, the modules take account of students' informal knowledge and thinking related to a topic. They also make connections with widely shared student experiences relevant to a topic. Equally, with a view to helping students understand how mathematics and science play a part in their wider and future lives, the modules try to bring out the human interest, social relevance, and scientific application of topics.

Finally, while the modules place a strong emphasis on exploratory talk and dialogic teaching, they also make provision for later codification and consolidation of key ideas, and build in individual checks on student understanding that can be used to provide developmental feedback.

