Modules for teacher training
(pre-service)

mascil aims to promote a widespread implementation of inquiry-based teaching (IBL) in math and science in primary and secondary schools. It connects IBL in schools with the world of work making math and science more meaningful for young European students and motivating their interest in careers in science and technology.
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1. Executive Summary

The mascil professional learning materials have been developed at the University of Nottingham, U.K., by wp4. These can currently be found at http://mascilite.mathshell.org.uk (pre-service).

The ‘international’ version of the materials at June 2014 (month 18) is a first draft: these will be updated as the project proceeds in light of feedback from across the partnership. The most up to date version of the toolkit at any point in time is therefore the online version. It is planned that this will be integrated as a part of the main mascil web presence now that the initial development phase is completed.

Fundamental to the project is the concept of professional learning that involves teachers and where possible trainee teachers in researching their practice in collaboration with colleagues in cycles of inquiry, ostensibly engaging in practitioner action research. This is taken into account in the design of the materials provided to tutors of trainee teachers.

The toolkit is designed in this way as a response to what we know from research about what makes effective professional development for teachers. The National Centre for Excellence in Teaching Mathematics in the UK in conducting a review of the literature found that effective professional development in mathematics education is:

- sustained over substantial periods of time
- collaborative within mathematics departments/teams
- informed by outside expertise
- evidence-based/research-informed
- attentive to the development of the mathematics itself.

Joubert and Sutherland, 2009.

These important factors in ensuring provision of high-quality professional learning are all addressed by the model of professional development advocated and supported by the mascil toolkit. Not only is the toolkit research-informed it also draws upon research wherever possible to inform teachers of what is know from research about aspects of teaching and learning and the use of mathematics and science in the world of work.

In developing the mascil toolkit for use with pre-service teachers we have ensured that it can support a model where trainee teachers work closely with in-service teachers so that such a collaborative community can learn together. Equally the flexible model we have designed can also be used to support more theoretically focused courses. Our rationale for this approach is because across the consortium, as evidenced by the national and international reports of work package 2 (deliverable 2.1), http://www.mascil-project.eu/reports-and-deliverables.html there will be many different modes of implementation – particularly in pre-service teacher education. In some countries there is little theoretical input to pre-service teacher, whereas in others trainee teachers spend considerable periods working directly in schools. This aspect of this multi-nation project is,
therefore, accounted for in the design of the professional development materials as a toolkit. This allows for customisation at a very local grain size by the tutor of an individual group.

The toolkit is developed around questions that teachers working in collaborative groups might wish to explore about their professional practice. These have been organised using a structure that is apparent in the top level menus of the toolkit. The MASCIL toolkit has three domains. **WAYS OF WORKING**: explains how to use the toolkit in a face-to-face mode as well as providing tools that will help groups consider how they will work together through cycles of inquiry into classroom teaching practice. **WORLD OF WORK**: supports new ways of teaching mathematics and science that connects with the world of work. It draws on the MASCIL resources that have been collected from across Europe to assist with this. **INQUIRY and IBL PEDAGOGIES**: provides support for teacher groups in exploring all aspects of inquiry in classrooms.

Within each domain a number of important issues are identified and within each of these the professional questions that teacher groups will potentially raise and about which their classroom inquiry might be focused.

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Fig. 1. Structure of the toolkit

To provide for the large variation in practice in pre-service teacher training the “international” English version provides a relatively large number of tools which can be tailored by partners to match the needs of the specific country’s systems and structures. Some customisation may be necessary for cases where within a country pre-service teachers have little opportunity for classroom experimentation.
2. Introduction - The professional learning toolkit (pre-service)

The mascil professional learning materials have been developed at the University of Nottingham, U.K., by wp4. These can currently be found at http://mascilite.mathshell.org.uk (pre-service).

The ‘international’ version of the materials at June 2014 (month 18) is a first draft: these will be updated as the project proceeds in light of feedback from across the partnership. The most up to date version of the toolkit at any point in time is therefore the online version. It is planned that this will be integrated as a part of the main mascil web presence now that the initial development phase is completed.

Fundamental to the project is the concept of professional learning that involves teachers and where possible trainee teachers in researching their practice in collaboration with colleagues in cycles of inquiry, ostensibly engaging in practitioner action research. Engagement in mascil professional development is more than taking part in a one-off course: it involves meeting on a number of occasions with opportunities for classroom enquiry to take place between meetings. This is taken into account in the design of the materials provided to tutors of trainee teachers.

The toolkit is a designed response to what we know from research about what makes effective professional development for teachers. The National Centre for Excellence in Teaching Mathematics in the UK in conducting a review of the literature found that effective professional development in mathematics education is:

- sustained over substantial periods of time
- collaborative within mathematics departments/teams
- informed by outside expertise
- evidence-based/research-informed
- attentive to the development of the mathematics itself.

Joubert and Sutherland, 2009.

It is generally agreed that professional development is more likely to be effective if it is sustained over substantial periods of time (Correnti, 2007; Guskey & Yoon, 2009). One successful approach has involved the development of collaborative communities of practice within mathematics departments (Lawrence & Chong, 2010; Nelson, Slavit, Perkins & Hathorn, 2008; Nickerson & Moriarty, 2005), often kick-started and sustained by outside expertise (Guskey & Yoon, 2009; Joubert, Back, DeGeest, Hirst & Sutherland, 2009; Potari, Sakonidis, Chatzigoula & Manaridis, 2010; Webster-Wright, 2009). There is evidence that research is not always used to inform the structural design or content of professional development (De Geest, 2010; Garet et al., 2001; Hemsley-Brown & Sharp, 2003; Hiebert, 1999; Rhine, 1998), and consequently there have been calls for more evidence-based practice and better use of research (Cordingley, 2008; Garet et al., 2001; Hiebert & Stigler, 2000; Wang, Spalding, Odell, Klecka & Lin, 2009). Further, it has been found that the most successful professional development for mathematics teaching pays attention to the development of the mathematics itself and particularly student learning (Chamberlin, 2005; Guskey & Yoon, 2009; Lau & Yuen, 2012).
Studies suggest that learning the mathematics of the elementary school curriculum deeply, increasing attention to student thought and examination of student work, changing beliefs about the nature of mathematics and what students can do, and participating in a supportive community are elements that support changes in instructional practice. (Nickerson & Moriarty, 2005, p114)

These important factors in ensuring provision of high-quality professional development are all addressed by the model of professional development advocated and supported by the mascil toolkit. Not only is the toolkit research-informed it also draws upon research wherever possible to inform teachers of what is known from research about aspects of teaching and learning and the use of mathematics and science in the world of work.

In developing the mascil toolkit for use with pre-service teachers we have ensured that it can support a model where trainee teachers work closely with in-service teachers so that such a collaborative community can learn together. Equally the flexible model we have designed can also be used to support more theoretically focused courses. Our rationale for this approach is because across the consortium, as evidenced by the national and international reports of work package 2 (deliverable 2.1), http://www.mascil-project.eu/reports-and-deliverables.html there will be many different modes of implementation – particularly in pre-service teacher education. In some countries there is little theoretical input to pre-service teacher, whereas in others trainee teachers spend considerable periods working directly in schools. This aspect of this multi-nation project is, therefore, accounted for in the design of the professional development materials as a toolkit. This allows for customisation at a very local grain size by a coordinator of an individual group through to a linear use of selected materials as a training course.

The toolkit is developed around questions that teachers working in collaborative groups might wish to explore about their professional practice. These have been developed around a working structure that is apparent in the top level menus of the toolkit.

The MASCIL toolkit has three domains.

**WAYS OF WORKING**: explains how to use the toolkit in both face-to-face and e-learning versions as well as providing tools that will help groups consider how they will work together through cycles of inquiry into their classroom teaching practice.

**WORLD OF WORK**: supports new ways of teaching mathematics and science that connects with the world of work. It draws on the MASCIL resources that have been collected from across Europe to assist with this.

**INQUIRY and IBL PEDAGOGIES**: provides support for teacher groups in exploring all aspects of inquiry in classrooms.

Within each domain a number of important issues are identified and within each of these the professional questions that teacher groups will potentially raise and about which their classroom inquiry might be focused.
For example, the screenshot below demonstrates how the question of “how should we use science tasks to connect to the world of work?” might be asked by teachers and this can be found in the domain “World of Work”. To address this particular question the tutor has available the tool WD-3 Connecting to the world of the horticulture industry. When a particular question has more than one tool available the tutor will need to make a choice of which tool(s) to use with the group being sensitive to their emerging needs.

To provide for the large variation in practice in pre-service teacher training the “international” English version provides a relatively large number of tools which can be tailored by partners to match the needs of the specific country’s systems and structures. Some customisation may be
necessary for cases where within a country pre-service teachers have little opportunity for classroom experimentation.

It is not expected that any group will use all of the tools made available: it is for the tutor to select what is most appropriate for their group from the tools made available.

It is important to note that the toolkit is written for use by, and written to directly address, the tutor of the trainee teachers.

References


doi:10.1007/s40299-012-0034-0


Potari, D., Sakonidis, H., Chatzigoula, R., & Manaridis, A. (2010). Teachers’ and researchers’ collaboration in analysing mathematics teaching: A context for professional reflection and


Mascil Pre-Service Toolkit

Welcome to the MASCIL toolkit for pre-service teacher education.

MASCIL aims to support teachers of mathematics and Science improve their teaching by adopting inquiry based learning (IBL) practices that connect with the world of work.

This toolkit can be used by course tutors in a totally flexible way to allow groups to work on aspects of teaching during a pre-service course.

The MASCIL toolkit has three domains.

- **WAYS OF WORKING**: explains how to use the toolkit as well as providing tools that will help groups consider how they may work together through cycles of inquiry into their classroom teaching practice.
- **INQUIRY and IBL PEDAGOGIES**: provides support for groups in exploring all aspects of inquiry in classrooms.
- **WORLD OF WORK**: supports new ways of teaching mathematics and science that connects with the world of work. It draws on the MASCIL resources that have been collected from across Europe to assist with this.

The diagram below provides an overview of the complete toolkit, with the domains on the left. These are then broken down into issues, with questions that groups might consider under each theme. Tools that the tutor can use when working with a group to answer these questions are then provided (in the right hand column of the diagram). Each part of the toolkit is accessible using the drop-down and fly-out menus above.
To get started read the "Ways of Working" page – select the page using the menu system or click here.

3.1 Domain: Ways of working

ISSUE: HOW DO I NAVIGATE AROUND THE TOOLKIT

The toolkit is written in html. It is designed so that it can be adapted for local needs by simply modifying the html.

There are two main things you need to know about the toolkit:

1. Using the menus
2. Using the tools.

1. Using the menus

Above the mascil logo on the toolkit you will find three main menus, which correspond to the three domains.
If you click on one of these (or hover) you find the menu (issues) in the case of Inquiry and Questions in the case of the World of Work.

2. Using the tools

The tools provide:
a) a short abstract of what happens in the face to face session with the teachers;

b) background information, rationale for the tool etc;

c) information about what you should do.

A number of icons are used for signposting:

Time: indicates the recommended minimum time to be spent on the tool (ranging from 10 minutes to 60 minutes) and appears on the left of the tool.

Ways of working: indicates how the teachers work together (whole group, small group, pair or individual) and appears on the left of the tool.

Next steps: suggests what you or the teachers might do next, where you might find out more information etc.

Download handout: indicates where there is a handout to download and appears on the right of the tool – clicking on this will open the pdf for you to view and download. It appears on the right of the tool.
General download: indicates where there is a document to download and appears on the right of the tool – clicking on this will open a pdf, document, picture, spreadsheet etc for you to view or download. It appears on the right of the tool.

Download PowerPoint: indicates where there is a PowerPoint to download and appears on the right of the tool – clicking on this will download the PowerPoint. It appears on the right of the tool.

Link to video: clicking on this links to a video. It appears on the right of the tool.
ISSUE: HOW CAN THE MASCIL RESOURCES BE USED.

There are two main types of resource provided by MaSciL:

1. The MaSciL pre-service toolkit - for tutors of trainees working towards becoming teachers of mathematics or science at Primary or Secondary levels.
2. Classroom materials - for teachers

Further details about each of these is given below.

1. The MaSciL pre-service toolkit

You are currently in the toolkit section of the resources which includes all of the important materials you need to support your trainees.

NOTE: The pre-service toolkit that you are using has been adapted from a version that supports the professional development of inservice teachers. this can be found here. The main changes made in adapting the toolkit have been to

- slim down the amount of material available
- adopt a more theory-based approach
- remove the expectation of being able to try out things in classrooms with pupils on a regular basis.

The Concept

The toolkit is organised in three domains:

Ways of working;

Inquiry and IBL pedagogies;

World of work.

Within each of these domains we have identified the key issues and then, for each issue, the questions that teachers may ask in relation to their professional role.

The MaSciL team has found that across Europe there is much variation in the professional preparation of teachers. There are instances of mainly theoretical university-based courses to
models that are entirely based in school and much more practical in their orientation. Consequently there is no one particular route through the materials that we can suggest. However, we do suggest that as a minimum you try to use some materials from both the Inquiry and IBL pedagogies and World of Work domains. This will give trainees some insight into how their teaching might open the minds of their students to the utility, purpose and intriguing world of mathematics and science.

2. Classroom materials

The teaching materials are an important part of the total package of resources available. However, they are meant to be illustrative of what is possible rather than providing an exhaustive bank of resources. Fundamental to MaSciL professional learning is that teachers – and trainee teachers – have opportunities to design their own tasks that promote IBL and connections with the world of work. This allows for careful customisation of resources that best suit a teacher’s working context and his or her students.

A link to these materials can be found here.

There is a MaSciL guide that provides advice about developing materials and this can be accessed here.
It is important for you as a tutor using the mascil toolkit to be familiar with the important principles included in the guide as these capture the essence of the approach being advocated. These principles are repeated below:

Redesigning a structured textbook task

Often, it is not necessary to start from scratch when designing tasks that fit the characteristics of MaSciL. The most common starting point is a textbook problem situated in a (rich vocational) context. The activities presented to the students will, in this case, be typical textbook problems: highly structured, closed, divided in sub-problems, with a lot of guidance. For this type of problem you may keep the setting (the context), but change the activities. This can be done by opening them up, stating a purpose or starting with an authentic overarching problem in order to support inquiry-based learning.

Connecting an IBL task to the World of Work

The starting point for a MaSciL task may be an existing IBL-task for mathematics or science that is not yet related to the World of Work. In this case it is often possible to add contextual information from the WoW, to formulate activities for the students, related to similar authentic practices from the WoW, to give students a professional role and to define an appropriate product.

Guidelines for (re)design

1. From a structured task to a task supporting IBL

Look for the ‘real problem’ within the context. Take this as the focal point for redesign

Create opportunities for students to become owner of the problem and a solution strategy

Skip sub-questions

Scaffold students’ inquiry process with a lesson plan (introduction, process support and final goal need more attention compared to a structured task)

Provide guidelines about the final evaluation
2. Connect to the WoW

Explore the context and try to relate this to the WoW

Think of a workplace practitioner and a workplace activity

Determine a product connecting to the WoW for an audience

3. Stimulate cooperation and communication

Ask for products that can be presented or discussed

Make sure the task asks for cooperative work (e.g. sharing of responsibilities)

Organise peer feedback

Finally, be aware of the changing role of the task in the learning process of the students. In addition to content-related goals, the new task aims at developing process skills. In some cases this might be at the cost of attention for content knowledge. In other cases it might offer opportunities to deepen content knowledge, or to better assess students’ abilities.
Fundamental to the MaSciL approach when working directly with inservice teachers is its foundation on what research tells us is effective in the learning of teachers as professionals:

- That an intervention needs to be **sustained** over substantial periods of time.
- That one successful approach involves **collaborative communities of practice** of teachers working to enquire into their professional practice.
- That such communities are often kick-started and sustained by **outside expertise**, provided by maybe a ‘trainer’ or a university educator.
- That the most successful professional development **pays attention to the development of the subject (mathematics or science), itself** and particularly student learning.

*(RECME Report: Joubert & Sutherland, 2008)*

Fundamental to the MaSciL model of inservice professional learning is that teacher groups work collaboratively to try things out in their classrooms. They take part in cycles of inquiry looking to see what works as they try to develop inquiry approaches to teaching and learning that connect learning to the world of work.

As Dana and Yendel-Hoppey (2008) write:

“The delivery of effective professional development has transitioned from the sole provision of in-service days where students have a holiday and teachers come to work to listen to an outside expert share knowledge about a new educational innovation to tapping the greatest underutilized source of knowledge about teaching and learning that exists within a school—the teachers and principals who work there! Two ways teacher and principal knowledge has been accessed to provide meaningful and powerful professional development are through professional learning communities (PLCs) and action research.”

It may be possible for you to adapt such an approach when working with trainee teachers. In some instances, for example, you may be able to use one of the tools from the toolkit and ask trainees to try something out with pupils in a school. This may not be possible because of the course nature, structure, timing and so on. However, even in such circumstances you may wish
to discuss with your group how they might research into their practice when they have an opportunity to do so.

A typical cycle of teacher inquiry is summarised in the diagram below.

*Teacher inquiry cycle.*

If you wish to share this diagram with trainees a handout is available.
In summary:

It is important to start with agreed values and aims for the group in general as well as in relation to what they will inquire into in particular. For example, at any particular moment in time the group may primarily be concerned about connecting learning to the world of work. At another point in time their concern may have shifted to primarily inquire into IBL pedagogies.

The group needs to define their inquiry focus and settle on a particular question that they will explore during this cycle of inquiry. If focussing on MaSciL issues the toolkit questions can assist in setting an agenda. For example, a group may want to explore working with different degrees of structuring of tasks.

A common plan of action needs to be developed: for example, will all teachers use the same tasks? will they use different tasks?

What ‘data’ will members of the group collect? By ‘data’ here we are referring mainly to qualitative data such as student work, an account of the lesson, photographs of the lesson and so on.

When the group next meet all members of the group should be able to describe what happened and what worked. It is reflection on these outcomes that is central to the group's professional learning: considering implications for their teaching practices is perhaps the most important part of the cycle. Each group meeting needs to plan time for this.


TOOL PDE-1A(T)

Initiate a group discussion about the teacher inquiry cycle. The diagram below will help with this discussion (Handout 1). It is important that the general principles of teacher inquiry are made explicit as they are fundamental to the MaSciL model of teacher development.
3.2 Domain: World of Work

MaSciL aims to promote widespread use of Inquiry Based Teaching in Maths and Science in ways that connects with the ‘World of Work’. The intention is to make learning more meaningful for students and consequently raise students’ interest in future careers in science and technology based areas. How, as teachers, we might connect school-based activity with the world of work raises many important issues and questions. In this domain of the MaSciL toolkit we provide support for pre-service teacher groups to explore three key issues:

- How do tasks bring learning to the world of work?
- How should we use maths tasks to connect to the world of work?
- How should we use science tasks to connect to the world of work?

Although not addressed here, your pre-service teachers may also be interested in the ways in which mathematics and science are used in the World of Work. You could refer them to the Mascil tools found [here](#).
ISSUE: HOW DO TASKS BRING LEARNING TO THE WORLD OF WORK?

Teachers can use tasks in a variety of ways to bring the world of work into the classroom. For example, they can use a work-based context for a science or mathematics task, which is often seen as motivating for students. However, it has the added benefit of raising students’ awareness of how important science and mathematics are in the world of work.

This part of the toolkit provides a tool that you can use with trainees so that they can explore the different ways in which tasks might be used to connect with the world of work. They are asked to categorise some tasks from the mascil materials database. These have been deliberately chosen to have a range of different qualities that should prompt discussion about their different intentions. Following this there is an opportunity for trainees to engage with some literature about ‘context’ and tasks. You may find it useful to have some typical textbooks available which trainees might then critique from this viewpoint.

Tool WC1 – Classifying and critiquing tasks
**Tool WC-1(T): Classifying and Critiquing Tasks**

Note: The five tasks to be used in this session should be circulated to the group as pre-reading so the trainees can become familiar with these before the session.

This tool introduces trainees to five examples of tasks that connect mathematics to the world of work from the Mascil database of classroom materials. The tasks have been chosen because they exemplify a range of different approaches to connecting the world of work to the classroom. It is the intention that the tool provides an opportunity to explore the different ways of making these connections.

The five tasks should already be familiar to the group:

- **Emergency Calls**
- **Telecommunication**
- **Entrance matting**
- **Container logistics**
- **ChocChip Mining**
Ask the trainees to work in small groups to examine the main features of each task. Each small group may be directed to look at a different task first so that all the tasks are covered by at least one group within the time available.

Watch the video of a discussion between teachers about these tasks before returning to small groups for further discussion of how the tasks might be placed into categories.

In small groups ask the trainees to place the tasks into categories and note their decisions on the hand-out provided. These categories are not predetermined and will arise from the discussions. The next slide can be used if necessary to assist in stimulating useful discussion.

The following questions may help stimulate useful discussion:

- Do workers really use mathematics and science in the way suggested by the task?
- When doing the mathematics or science required with the task could students forget about the context or does it remain important?
- Does the task have any features that result in mathematics or science being used in ways that are different from those usually used by students?

Wiliam (1997) suggests that contexts used in mathematics classrooms can be classified as follows:

- Contexts with little relation to the mathematics being taught (mathematics looking for somewhere to happen);
- Contexts with a structure that maps to the mathematical structure being taught (‘realistic’ problems);
- Contexts in which the primary aim is to resolve a problem and no mathematics is needed (real problems).
- The full article may be obtained here.

Ask trainees to discuss how this information relates to the categories that they developed?
Bring the group together to share the main points from their discussions.

Trainees should now consider how they might use the tasks with a class. They may find it helpful to consider the following questions:

1. Does the task require students to adopt a role or ways of working that are different to usual?
2. What knowledge, skills, or understanding might be gained, either mathematical or science-related or otherwise, through using this task?
3. In what ways might this learning be different from that stimulated by a more conventional school task?
4. Would the task help motivate students or stimulate student inquiry in any way?

As a next step the trainees might use opportunities in their own teaching, or during lesson observations, to identify further examples of tasks that connect mathematics to the world of work. Trainees should be ready to report back on any examples found and how the connections were made at the follow-up session.
Issue: How Should We Use Maths Tasks to Connect to the World of Work?

The Mascil repository at [http://www.fisme.science.uu.nl/publicaties/subsets/mascil/](http://www.fisme.science.uu.nl/publicaties/subsets/mascil/) provides a range of tasks which could be used to connect classroom learning to the world of work. There are also various national repositories which teachers could explore to find tasks which would serve the purpose. For example see the [National Stem Centre](http://www.nationalstemcentre.org.uk/) in the UK. This provides a national library of many curriculum materials from the past that have been digitised and are freely available to all teachers.

One tool provided here allows you to explore with trainees how teachers of mathematics might use tasks to connect learning to the world of work.

**Tool WE-1: Architecture**
Tool WE-1(T): Architecture

This activity explores a classroom activity set in the context of the architecture industry. The classroom activity involves watching a video, performing a design task which uses mathematical modelling, reporting on the design and finally considering what it is like to work as an architect.

This tool provokes trainees to think about how students might respond to the classroom activity and how they might adapt the lesson plan.

Together watch the video Architecture-NCETM and think about the ways in which this video might be used:

a) as stimulus material for a mathematics inquiry;
b) as a way to bring the world of work into the mathematics classroom.

Discuss the group's responses to the video, highlighting in particular, ideas about how, and how well, this video might bring the world of work into the classroom. The following questions might stimulate the discussion:

• Is this a workplace context that students are likely to recognise?
In which ways could you encourage students to think about mathematical questions that arise from the context?
In which ways, and to what extent, does the video provide some careers guidance?

Give the trainees the handout Student responses to the Architecture task which shows:

- the questions given to the students;
- questions for the trainees about the activity.

Ask them to work with someone else to imagine how students might respond to the task. They should complete the handout and answer the questions:

- What mathematical learning are students likely to take away from this task?
- What difficulties might they have with a) understanding what mathematics is needed and b) using mathematics to model the situation?
- What might students learn from the video?
- How well would this activity work for students in terms of bringing the world of into the classroom? Why?

As a group, discuss the students’ predicted responses. The trainees should then read the extracts on the handout Mathematics in the workplace by Hoyles et al (2002) and Hodgen and Marks (2013), together with an example of what workplace mathematics might look like taken from Williams and Wake (2007b). The two reports are available at: here (Hoyles) and here (Williams and Wake).

To stimulate discussion you might ask trainees to consider how well they think their own mathematics learning prepared them for making sense of the formula in the extract from Williams and Wake. Ask them what they know that helps them make sense of the worker’s version of the

To further stimulate discussion ask the group to consider how the findings of Hoyles and colleagues and Hodgen and Marks are exemplified in the example provided by Williams and Wake.

As a group discuss the issues raised by these extracts about the mathematical skills that students are likely to require for the workplace and how these might be developed through this task.

As a next step trainees might think about the ways in which the task could be used in the classroom and develop their thinking into a lesson outline.
ISSUE: HOW SHOULD WE USE SCIENCE TASKS TO CONNECT TO THE WORLD OF WORK?

The Mascil repository at http://www.fisme.science.uu.nl/publicaties/subsets/mascil/ provides a range of tasks which could be used to connect classroom learning to the world of work. There are also various national repositories which teachers could explore to find tasks which would serve the purpose. For example see http://www.nationalstemcentre.org.uk/elibrary/science/. This provides a national library of many curriculum materials from the past that have been digitised and are freely available to all teachers.

One tool provided here allows you to explore with trainees how teachers of science might use tasks to connect learning to the world of work. This tool is based on a science task from the Nuffield Foundation in the U.K which has for many years supported curriculum innovation in the teaching of science. Follow the link here to go to their project Practical work for learning.

Tool WD-3: Connecting to the world of the horticulture industry
Tool WD-3(T): Connecting to the World of the Horticulture Industry

This activity explores a task set in the horticulture industry. The horticulture industry involves handling plants at all stages of growth and working to produce healthy plants. Economic considerations mean that each plant is an investment for the business and wastage must be minimised. An understanding of plants and how a scientific approach can inform decision-making is essential in this industry.

To begin, watch the video *Horticulture video* and think about the ways in which this video might be used a) as stimulus material for a science inquiry and b) as a way to bring the world of work into the science classroom.

Discuss the group’s responses to the video, highlighting in particular, ideas about how, and how well, this video might bring the world of work into the classroom. The following questions might stimulate the discussion:

- Is this a workplace context that your students are likely to recognise?
- In which ways could you encourage them to think about scientific questions that arise from the context?
- In which ways, and to what extent, does the video provide some careers guidance?
- Participants should now be given the student questions.

Participants should now be given the student questions.

Ask them to imagine how their students would respond to the task and to work with someone else to fill in the handout *Student responses to the Horticulture task.*
Bring the group together again and hold a short discussion in which they share their thoughts.

### 3.3 Domain: Inquiry and IBL Pedagogies

Mascl is predicated on the view that inquiry learning brings benefits but that both teachers and students find this approach challenging. One of the Mascl partners, Suzanne Kapelari, talks here about her understanding of IBL.

An important aspect related to teaching using inquiry based learning is a shared understanding of what we mean by ‘inquiry’. The Eurydice report *Science Education in Europe: National Policies, Practices and Research* (Eurydice, 2011a) explores the notion of inquiry learning in some detail, stating that:

“A model to deal with different forms of inquiry approaches is proposed by Bell et al. (2005). They describe a model that includes four inquiry categories which vary according to the amount of information provided to the student. The first category, ‘confirmation inquiry’, is the most strongly teacher-directed in which the student is provided with the most information, the other levels are known as ‘structured inquiry’, ‘guided inquiry’, and ‘open inquiry’. At the ‘confirmation’ level, students know the expected outcome; at the other end of this scale (‘open inquiry’), students formulate questions, choose methods and propose solutions themselves." (p. 70).

However, the same report also quotes Barrow (2006), stating that

“Inquiry is a huge area of research, and yet it is still without any consensus about what constitutes inquiry” (p.105).

In terms of learning, the inquiry-based approach is about engaging students’ curiosity in problems in the world and the ideas that surround them. In the workplace, this might mean observing and posing questions about situations. If their questions are too complex, they may try to simplify or model the situation. They may then try to answer their questions by collecting and
analyzing data, making representations and by developing connections to their existing knowledge. They then try to interpret their findings, checking that they are accurate and sensible, before sharing their findings with others.

This process is often missing in the school classroom because the teacher often points out what must be observed, provides the questions, demonstrates the methods to be used and checks the results. Students are merely asked to follow the instructions.

This domain provides tools to provoke

- thinking about inquiry learning on an abstract level
- experiences of what it feels like to work on tasks designed for inquiry learning
- reflections on the changing roles that are necessary for students to share this experience in the classroom.

We suggest you work through some or all the tools with your trainees to consider what is effective in using inquiry approaches. You might also use some of the tools in other parts of your training courses as they cover aspects of teaching that are not only applicable to inquiry approaches: For example, tools are provided that allow trainees to consider effective questioning and collaborative working.
ISSUE: THE INQUIRY CLASSROOM

According to Barrow (2006)

“Aspects of inquiry teaching include strategy to assess students’ prior knowledge and ways to utilize this information in their teaching; effective questioning strategies, including open-ended questions; long-term investigations, rather than single-period verification-type investigations, and so forth.” (p. 271).

Three questions aim to provide trainee teachers with opportunities to think about inquiry learning and how their classroom actions might encourage their students develop inquiring minds in mathematics and science.

These are:

- What happens in an IBL classroom?
- Does IBL work?
- How do we support IBL?
What Happens in an IBL Classroom?

In this part of the toolkit you will find two tools that aim to help trainee teachers understand more about the nature of inquiry teaching and learning by focusing on what could be expected within an inquiry classroom. The tools included are:

- Characterising an IBL classroom
- Observing an IBL lesson
Tool IA-1(T): Characterising an IBL Classroom

This tool allows groups to consider the characteristics of classrooms where students are engaged in inquiry based learning. Trainees will watch a video which exemplifies an IBL lesson in which students are working on the problem ‘Building with plastic bottles in Honduras’. They are then asked to think about the main characteristics of the lesson and how they compare to IBL approaches.

Show the video of an IBL lesson: ‘Building with plastic bottles in Honduras’. Ask the trainees to look out for the main features of the lesson, observe what the teacher does, what the students do, and make a note of where they see each of the main characteristics of IBL.

Ask them to work in groups to think about the main characteristics of the lesson and how they compare to IBL approaches. Ask groups to prepare a poster that sets out the key aspects of IBL approaches that they have identified and agreed.

Show the trainees this list of characteristics of IBL approaches:

- Student led inquiry
- Tackling unstructured problems
- Learning concepts through IBL
- Questioning that promotes reasoning
- Students working collaboratively
- Building on what students already know
- Self and peer assessment
Certain characteristics have been identified as being important by the MaScil team and these are shown on the handout *Characteristics of IBL*. MaScil, building on the work of the PRIMAS project, has identified these important characteristics of IBL and additionally how the world of work might be connected to such learning. You can use this diagram to add texture to the list discussed previously.

Further discussion of issues in relation to possible concerns about how inquiry practices might be implemented can follow a return to discussion about the lesson that the group have observed.

Ask the trainees to work in pairs to reflect on the main features of the lesson and where they saw the characteristics of IBL in the lesson.

Bring the group together for a whole-group discussion of where they observed the characteristics of IBL in this lesson. You may wish to ask them to contrast this with teaching they have observed in schools recently.

The article by Artigue and Blomhøj, which was in the 2013 Special Issue of ZDM about IBL raises some concerns and issues about conceptualising inquiry based mathematics education in different settings. If you have an opportunity ask the group to read the article and consider:

- Which of these issues and concerns are most applicable in their situation?
- Why is that?
- Can they be overcome?
- Should they be overcome?

Encourage your trainees to:

- Watch some of the videos of inquiry lessons found here <<<give web address>>
• Read more about IBL in the ZDM special issue about this at http://link.springer.com/journal/11858/45/6/page/1
Does IBL Work?

Mascil is underpinned by a belief that inquiry learning is beneficial but many teachers and other professionals in education question whether inquiry approaches actually work, and work as well as more traditional approaches.

This part of the toolkit provides a tool which you could use with your trainees to explore more about what is known about inquiry learning and, crucially, how (trainee) teachers can convince themselves that inquiry approaches work well.

The tool ‘Exploring evidence’
Tool IB-2(T): Exploring Evidence

This is a discussion activity which draws on research findings to think about what claims teachers can make related to the effectiveness of an inquiry approach. It is suitable for trainees of mathematics and science.

Begin by discussing with the trainees how they would know if these approaches work. They might suggest, for example, greater student engagement or better student learning.

Ask the trainees to read the brief extracts from various research articles that engage in discussion and debate about whether IBL approaches work. They should look at these critically.

Extract 1 is taken from the paper Inquiry-Oriented Instruction in Science: Who Teaches That Way? (Smith et al, 2007) and refers to Anderson’s hesitant conclusion from an earlier article. The full paper can be found here.

Questions that you can use to stimulate debate include: (In relation to extract 1)

- Why might there only be small scale qualitative studies conducted that support inquiry approaches in science?
- What counts as “can work”

Extract 2 is taken from the paper Open and Closed Mathematics: Student Experiences and Understandings (Boaler, 1999). Ask the trainees to discuss the outcomes indicated here from alternative approaches. The full paper can be found here.

Questions that you can use to stimulate debate include: (In relation to extract 2)

- Is procedural knowledge always of limited value?
- Don’t we all seek to proceduralise complex tasks?
- Why not assist students in doing this?
Show them the extract taken from the paper Inquiry-Oriented Instruction in Science: Who Teaches That Way? (Smith et al, 2007) and ask them to discuss Anderson’s hesitant conclusion reported by Smith et al.

By critically comparing the (selected) evidence from the research reports, discuss the value of the findings and the possible outcomes for students.

Following the session trainees may read the full reports (or be directed to further reading) to consider the implications for teachers and students of an inquiry-based approach.

For example, see the Hampden-Thompson and Bennett 2013 paper in IJSE which claims that:

“there is an association between students’ motivation towards science, enjoyment of science and future orientation towards science, and the frequency in which various teaching and learning activities take place in the classroom”.

Trainees may also find the meta-analysis of published papers in science education, produced when inquiry was meant to be the ‘way of teaching’ between 1996 and 2006, interesting. This paper concluded that:

“Studies that contrasted epistemic activities or the combination of procedural, epistemic, and social activities had the highest mean effect sizes. Furthermore, studies involving teacher-led activities had mean effect sizes about .40 larger than those with student-led conditions.”

How Do We Support IBL?

Using inquiry approaches in the classroom represents a significant shift in practice for many teachers.

This part of the toolkit provides some tools which you can use to support your trainees in implementing IBL approaches. Some of the tools are drawn from the Primas project, which developed detailed and extensive professional development resources. These can be found here.

Mascil’s tools are:

- **Tool ID-1: Classroom questioning discussion**
- **Tool ID-2: Classroom questioning role play**
- **Tool ID-3: Planning for effective questioning**
- **Tool ID-4: Students working collaboratively**
Tool ID-1(T): Classroom Questioning Discussion

In this activity trainees consider the sorts of questions teachers ask, first as a whole group and then in pairs.

Hold a group discussion about the types of questions teachers ask, considering the following:

- What different types of questions do teachers ask?
- What different functions do these questions serve?
- Which types of questions are used most frequently?
- What common mistakes are made when asking questions?
- What are their effects?

Ask the trainees to work in pairs to think about both barriers and dilemmas within their own practice. Ask them to write their responses on the handout. They should discuss together:

- The different kinds of questions they use
- The functions of their questions
- The questions they use most often
- Their common mistakes and the effects

Bring the group together again and ask them to share their thoughts. The possible reasons for asking questions might include 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.

Ask the group to read the extract from the work of Black and Wiliam on the handout. This gives conclusions from an extensive review of the literature in relation to formative assessment and the extract focuses on their conclusions in relation to classroom questioning.

Ask the trainees to consider how their critique of common questioning techniques applies to their recent observations of classrooms and how IBL tasks might help teachers ask questions that are more productive in encouraging students to think and understand mathematical and scientific ideas.

The following list shows some of the common mistakes referred to by Black and Wiliam:

- 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.
As a follow up to this session Tool ID-2(T) will provide further opportunities to explore the use of questioning in IBL approaches.
**Tool ID-2(T): Classroom Questioning Role Play**

This activity begins by watching a short video on questioning, followed by a role play in which trainees experiment with different questions. This activity could be used immediately after Tool ID-1.

Show the video on questioning strategies. Ask the trainees to think about how the video relates to their own practice and their own subject specialism, if appropriate.

Set up a role play: Agree with the whole group the classroom context (age of pupils, subject, aim of lesson and so on).

Ask the trainees to work in small groups to devise some effective questioning to use in this context. For each small group, one participant should act as the teacher and the other trainees as students. Try out the questions devised by the small group.

Together reflect on why and how the questions were (or were not) effective, possibly using one or more of the following questions:

Pick a question.

- What opportunities did it provide for the student?
- What did it provide for the teacher?
- In which ways was it an effective question?
- Did the question get the sort of response that was predicted?
- What different sorts of questions were used?
Bring the group back together and ask the small groups to share their thoughts.

Encourage the trainees to use opportunities that occur to view some other lessons (through the media or classroom observations), reflect on the questions used and draw some conclusions about their effects.

**Tool ID-3(T): Planning for Effective Questioning**

In this activity trainees consider the sorts of questions teachers ask, first as a whole group and then in pairs.

Begin with a brief discussion on classroom questioning, particularly if you have not worked through tools ID-1 and ID-2. Discussion might be prompted by the questions:

- What kinds of questions should teachers ask?
- Which questions encourage student inquiry?

Now ask the trainees to work in pairs to discuss the questions on the handout *What kinds of questions promote inquiry-based learning?* and record their responses. The key questions are:

- What types of questions promote inquiry-based learning?
- What examples can you provide?
Bring the whole group together. Share some thoughts from the small group session. Make available copies of the handout *Five principles for effective questioning*.

This summarises some research findings related to 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.

Ask the trainees to discuss the principles in small groups, perhaps focusing on these questions:

- Which of these principles might be most frequently observed in classrooms?
- Which principles do teachers find most difficult to implement? Why is this?

Ask the trainees to select one lesson in their subject area from the Mascil repository, and plan a lesson that will promote thinking and reasoning. They could do this in the session or at home. The handout *Planning for effective questioning* will support the trainees as they plan. Also encourage them to think about these questions:

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

The list provides some of the more common mistakes that are sometimes recorded.

- 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.

Ask the trainees to read the extract from Working inside the Black Box which is a follow-up publication to Inside the Black Box. This gives a brief account for a professional audience of a research project in which Paul Black and Dylan Wiliam worked with teachers to explore how research evidence could be used to support effective change in teaching practice. If possible have a whole-group discussion about the implications of this for your practice when you become a teacher.
This tool involves a discussion about constructive classroom talk between students which is followed by an overview of the teacher’s role in the classroom when the students are working in small groups. The group then watches a video of a classroom lesson and analyses what happens.

Introduce the topic briefly to the trainees, emphasising that collaborative work is common in the world of work. Ask them to share with the group some of their experiences of what happens in their classrooms when students work collaboratively in small groups. They may bring up a range of issues, both positive and negative. We have found that teachers talk about:

- Benefits of students discussing with one another (e.g. learning from each other, positive effect on self-esteem)
- Obstacles to classroom discussion (e.g. lack of time, feeling that they are out of control)
- The need for ground rules (e.g. allowing everyone a chance to speak, building on what others say)
- Students need to share goals and understand individual responsibilities
- The role of the teacher (e.g. listening before intervening, making the students do the thinking)

Now ask the trainees to work in pairs on one of the tasks on the handout. There is plenty to do in this tool so we suggest you give them no more than about 10 minutes; the important thing is that they get started.
Suggest that they choose together which task to work on and then spend a few minutes thinking about it on their own. They should then compare their ideas and try to refine their answers together.

Bring the group together and ask them to reflect on the experience they have just had. They will probably have much to say, but if not, you get get them started with questions such as these: (note that not ALL these questions are on the slide)

- Did you find it helpful to have a chance to think about the question yourself before it was discussed in your group?
- How far did you really think together, or did you tend to follow independent lines of thought?
- Did someone ‘take over’? Was someone a ‘passenger’?
- Did you listen to, share ideas with and consider the alternative views of everyone in the group?
- Did you build on each others’ ideas to construct chains of coherent reasoning?
- Did you feel able to share your ideas without fear of embarrassment of being wrong? Did anyone feel uncomfortable or threatened? If so, why?
- Did your discussion stay ‘on task’ or were you ‘wandering’?
- What are the implications of this activity for your classroom?

Give the trainees the handout, which has three sections:

- Characteristics of helpful and unhelpful talk (a summary taken from research)
- The teacher’s role during small group discussion (a summary taken from research)
- Observing and analysing a discussion lesson (questions for pair work).

Ask them to quickly read through sections 1 and 2, as they will want to draw on these in the observations and analysis of the lesson (section 3). Tell them that you are going to show them a video, and ask them also to prepare by reading through section 3.
Show the video and have a whole group discussion about what they have observed. Ask them:

- Where did you see instances of cumulative, disputational, exploratory talk?
- What do you think was the impact on learning of this?
- What role did the teacher play in facilitating this talk?

Further research about collaborative working can be found on the handout.

An article by Webb gives some theoretical perspectives on student learning during collaborative group work. You may like to consider this from your own perspective as a learner.
Issue: IBL in Mathematics

This part of the toolkit considers how the processes of inquiry based learning may be integrated into the teaching of mathematics content.

In many schools these two aspects of learning are kept separate; content is taught as a collection of facts and skills to be imitated and mastered, and/or process skills are taught through investigations that tend not to have the development of content knowledge as a priority.

The integration of content and process raises many pedagogical challenges.

The processes under consideration here are:

- observing and visualising;
- classifying and creating definitions;
- making representations and translating between them;
- finding connections and relationships;
- estimating, measuring and quantifying;
- evaluating, experimenting and controlling variables.

As some have pointed out, these are developments of natural human powers that we employ from birth (Millar, 1994). To some extent, we use them unconsciously all the time. When these powers are harnessed and developed by teachers to help students understand the concepts of mathematics and science, students become much more engaged and involved in their learning.

This part of the toolkit asks the following questions.

- What do inquiry tasks in mathematics look like?
- How do we plan for IBL in mathematics?
- How does IBL relate to our curriculum?

The tools provided allow you to consider important issues relating IBL and teaching mathematics in particular.
What Do Inquiry Tasks Look Like in Mathematics

It is not difficult to find inquiry tasks for mathematics, although we would like to emphasise that a task *in itself* is not an inquiry task. The way it is approached by the teacher (and the students) is crucially important, and for more guidance on how to use an inquiry approach see this section of the toolkit.

Mascil’s repository provides a range of different tasks that can be used in inquiry learning.

Others can be found on

- the Mathematics Assessment Project website (look for the ‘problem solving’ tasks
- the Primas website
- the National STEM Centre
- NRich.

This toolkit provides a tool that you can use with trainees to explore the question of what inquiry tasks look like.

Tool IE-2: Comparing structured and unstructured problems
This activity begins with a short introductory discussion, which is followed by paired work in which the trainees compare structured and unstructured versions of the same problems. The group then comes together to share their thoughts.

Hold a short discussion to introduce the topic. Discuss how in most mathematics and science classrooms, students are provided with structured tasks and are told precisely which techniques to deploy. Students learn by following instructions. Problems and situations that arise in the world are not usually like this. Rather than being exercises in the use of a particular skill or concept, real-world problems require students to make simplifications, model situations, choose appropriate knowledge and processes from their ‘toolkit’, and test whether their solution is “good enough” for the purpose in hand. It seems logical that if students are to learn to use their skills autonomously in their future lives, they will need some opportunities to work on less structured problems in their classrooms.

Ask the trainees to work in pairs or threes. Give them the handout, which contains both structured and unstructured versions of two inquiry (problem solving) tasks set in different workplace contexts. It also provides sample responses to the unstructured problems. Ask them to compare the less structured versions of the problems with the structured versions. Ask them to consider the following questions:

- What decisions have been left to the students?
- What pedagogical issues will arise when teachers use unstructured problems like this?
Students working on the table tennis tournament problem.

Bring the group together and ask each pair to share their thoughts. Make a list of the points they make. Some issues that may be raised are:

- unstructured problems are more difficult;
- it is more difficult to plan a lesson with these problems;
- students may not even know how to get started on them;
- students will not necessarily use what we have taught them;
- if we offer help too quickly, students will simply do what we say and not think for themselves;
- students will generate a greater variety of approaches and solutions;
- students may need reassurance that it is OK to try a different approach or reach a different conclusion.

Encourage the trainees to design an unstructured version of a problem (ideally of one they have already taught in a more structured form). Where possible trainees should try teaching their unstructured version and be prepared to report back at the next session.
How Do We Plan for IBL in Mathematics

Teachers frequently ask for guidance on how to plan for IBL teaching. This provides an additional challenge for trainee teachers as not only do inquiry approaches require considerable careful thought they are not yet proficient and experienced at planning more generally.

Here we provide a tool that you can use with trainees to support them in learning to plan for IBL.

Tool IF-3: Advice for teaching problem solving
This activity addresses some of the difficulties that many teachers have when they teach problem solving in mathematics. The trainees discuss what may be difficult about teaching problem solving and possible strategies, before exploring some research-based approaches. It is helpful to start with a problem for trainees to explore.

Ask the trainees to spend some time working on the task 110 years on in small groups. This is not set in a world of work context although it allows students involved in it to experience the type of problem solving skills that are valued in many work places. For example, it involves having to make assumptions, estimate likely values, approximate and so on. It is important that trainees have sufficient time to experience enough of the challenges that the problems poses for them as problem solvers before moving on to consider implications for teaching.

Consider the examples from students who worked on this task. These were done in a classroom in England and they are not translated. However, it is interesting to ask trainees to consider the diagrams that have been produced by students to represent their thinking and contrast these with their own.

You may find the schematic overview (provided as a PowerPoint slide) of the problem solving cycle helpful when discussing the important processes with trainees. This summarised in the handout *Mathematical Problem Solving* that will be given out later in the session.

After trainees have had an opportunity to work on the task hold a discussion with them about the issues that arise in teaching students how to solve problems like this. Ask them to share their thoughts about teaching problem solving: what may be challenging? Why? What strategies may be successful?
At this point you may want to share the handout *Mathematical problem solving*. This has been adapted from a document used with teachers working on the project LeMaPS in England available at [http://www.lemaps.org](http://www.lemaps.org)

If the following points about scaffolding have not been covered then these should be raised with the group.

Bruner uses the metaphor of *scaffolding* to describe the structuring that a teacher provides (Wood, Bruner, & Ross, 1976). The teacher encourages students to do as much as they are capable of unaided and only provides the *minimum* of support to help them succeed. This support may involve reducing their choices, drawing attention to important features through questioning, or even at times demonstrating what to do.

In his work with young children, Wood (1988) categorised different levels of scaffolding, from less directive to more directive: giving general verbal advice, giving specific verbal instructions, breaking the problem down, demonstrating a solution. Wood also introduced two rules of contingency:

“Any failure by a child to succeed in an action after a given level of help should be met by an immediate increase in help or control.

Success by a child then indicates that any subsequent instruction should offer less help than that which preceded the success, to allow the child to develop independence.” Wood (1988)

The important idea here is that scaffolding should be removed as the student begins to cope, otherwise it reinforces dependency.

The handout *Practical advice for teaching problem solving* suggests provides some practical strategies for teachers when using unstructured problems in the classroom. Ask the trainees to work together in small groups and give each small group a copy of the handout. Ask them to

- discuss which ideas might be most difficult to implement;
- think of examples of what teachers might say to students;
• add these to the cells in the right hand column.

Bring the group back together and encourage the trainees to share ideas from their small group discussions:

• What were the main points that arose in discussions?
• Share any ideas that emerged about what teachers might say to students.

When collaboratively working on problem solving it is important that students become involved in discussion with one another. This poses yet another challenge for the teacher. Mercer (2000) describes several types of classroom talk in his book Words and Minds. He describes exploratory talk as follows:

“Exploratory talk in the classroom means speakers build on and elaborate on ideas in a collaborative manner through critical and constructive exchanges”.

Trainees could use opportunities in lesson observations to identify examples of exploratory talk and how this was encouraged amongst students.

Further reading on ‘scaffolding’ and supporting students can be found in:

The role of tutoring in problem solving (Wood, Bruner, & Ross, 1976) available here.

Learning and Doing Mathematics (Mason, 1989).
How Does IBL Relate to our Curriculum?

Teachers ask where in the curriculum they should use IBL. They want to know how IBL relates to their own curriculum whether this be nationally, regionally or locally determined.

Different countries have different curricula, so the tool provided here can be used in any setting. You will need to have copies of the curriculum that your trainees will work with ready for use with this tool.

**Tool IG-1: The potential of IBL to meet curricular demands in mathematics**
Tool IG-1(T): The Potential of IBL to Meet Curricular Demands in Mathematics

This tool promotes reflection on teaching practices and analyses what approaches may best address current educational demands. To begin the group considers what students learn by engaging in inquiry tasks. They go on to find where and how their curriculum documents relate to this type of learning, and to consider how and when they could teach towards this.

Begin by asking the group what mathematics they think students learn by engaging in IBL. They may have ideas about content but should also consider ‘competences’ or ‘process skills’ such as those listed in the Eurydice report *Mathematics Education in Europe: Common Challenges and National Policies*. Draw the attention of the trainees to the five areas of competence highlighted in this report:

- mastering basic skills and procedures;
- understanding mathematical concepts and principles;
- applying mathematics in real-life contexts;
- communicating about mathematics; and
- reasoning mathematically.

Now ask the trainees to work in pairs. Provide each pair with a copy of curriculum documents which lay out what should be taught and learned. Ask them to go through these documents to find out which of these, or similar, skills is identified in the curriculum and where. Tell them you want them to think about how and when they could/should teach in order to promote these competences.

Bring the group back together, and share the main points from the paired discussions.
Consider the ways of teaching mathematics and the associated purposes shown on the handout *Purposes of learning mathematics*. Discuss the knowledge and competencies that might be developed through the contrasting examples on the handout. Page 2 of the handout gives a further perspective on the role that mathematics has to play in the education of young people. This extract is taken from the literature that discusses how there is something of a convergence of mathematics curricula across the world. You may wish to have a brief discussion of this phenomenon with your trainees.

As a whole group try to summarise how IBL can begin to address the curricular demands of mathematics, considering both the curriculum content and competencies.

As a next step encourage the trainees to select one element from the curriculum and design a short task with an IBL approach that will help develop both curriculum knowledge and some relevant competencies. Direct them to consider one or more of the MaSciL resources to stimulate their thinking.
IBL in Science

This part of the toolkit considers how the processes of inquiry based learning may be integrated into the teaching of science content. Arguments for inquiry based learning in science have been made on the basis of:

- IBL being a more effective pedagogical approach to teaching science content;
- IBL being important in terms of teaching about aspects of the Nature of Science and how scientists work;
- IBL supporting the teaching of processes and skills, with the further potential to support transferability of skills through positioning inquiries within authentic contexts.

The arguments are often linked to the need to produce future scientists, those who will go on to use some aspects of science within their workplaces, those who will need the kinds of transferable skills that can be taught well within the discipline of science and the need to develop a public with sufficient understanding of science to take responsible positions as citizens.

The emphasis on particular aspects of these arguments varies across countries and schools. However, the position in many schools remains one where the teaching of science content is kept separate from the teaching of processes, skills and the nature of science. Content is taught as a collection of facts and ideas to be learnt and understood, while manipulative and process skills are taught separately through practical activities. Some schools include practical activities with strong elements of investigation in them but many do not and it is more common for the focus to be on either an illustration of science content or learning a particular practical skill.
The integration of content and processes within IBL raises many pedagogical challenges. The processes include those of observing and visualising; classifying and creating definitions; making representation; finding connections and relationships; estimating, measuring and quantifying; evaluating, experimenting and controlling variables. As some have pointed out, these are developments of natural human powers that we employ from birth (Millar, 1994). To some extent we use them unconsciously all the time. When these powers are harnessed and developed by teachers to help students understand the concepts of mathematics and science, students become much more engaged and involved in learning.

Two tools were provided in this section of the toolkit:

- The potential IBL to meet current curricular demands?
- Evidence in science

The tools provided allow you to consider important issues relating IBL and teaching mathematics in particular.
How Does IBL Relate to our Science Curriculum?

Teachers ask where in the curriculum they should use IBL. They want to know how IBL relates to their own curriculum whether this be nationally, regionally or locally determined.

Different countries have different curricula, so the tool provided here can be used in any setting. You will need to have copies of the curriculum that your trainees will work with ready for use with this tool.

Tool IG-1: The potential of IBL to meet curricular demands in science
Tool IJ-1(T): The Potential of IBL to meet Current Curricular Demands in Science

This tool promotes reflection on teaching practices and analyses what approaches may best address current educational demands.

To begin the group considers what the international assessments (TIMSS and PISA) bring to pre-service teachers’ perspectives of inquiry and consider the current thinking about science curriculum for school students.

The pre-service teachers then explore the meaning of ‘inquiry’ in the frameworks of TIMSS and PISA and explore how inquiry is manifest in their own curriculum documents.

To better understand ‘inquiry’ the pre-service teachers asked to brainstorm ideas and identify what sorts of activities are evident in an inquiry classroom and the challenges in working with inquiry as a focus.

The trend across the world in education is that students learn by engaging in inquiry tasks. Pre-service teachers will explore how and when they could teach for this kind of learning.

Finally, pre-service teachers will read a meta-analyses of inquiry in science classrooms to learn about what forms of inquiry are considered to be best practice, how these forms of inquiry are explored in the PISA 2015 frameworks and how to best plan for inquiry.


Peer reviewed papers:

- Salter & Atkins (2013)
- Hannaur, Jacobs-Sera, Pedulla, Cresawn, Hendrix & Hatfull (2006)
- Windschitl, Thompson & Braaten (2008)
- McConney, Schibeci, Oliver, Maor & Woods-McConney (in press)

National science education standards, policy and national curriculum (to be provided by educators, according to any national or local contexts)
Key questions to work with trainee teachers about how IBL relates to our science curriculum (included in the text)

The development of large-scale international assessments has led to comparative analyses of education systems at national policy level. These include the Programme for International Student Assessment (PISA), a triennial international survey involving the OECD countries, for 15 year old students, the Trends in Mathematics and Science Studies (TIMSS) held every four years for students in year 4 and year 8 and the Progress in International Reading Literacy Study (PIRLS) which measures and documents the trends on reading in year 4 students. For teachers of science, therefore, the results and discussion around PISA and TIMSS are most pertinent.

In 2006, the focus of student assessment was science and will be the focus in 2015. The framework for PISA 2015 is to determine what students can do at aged 15 in regards to scientific literacy. Far from being a test of recall, scientific literacy in PISA 2015 has been conceptualised as “three competencies:

- to explain scientific phenomena,
- evaluate and design scientific enquiry and
- interpret data and evidence scientifically” (draft framework for science 2015, page 6)

The framework also describes scientific literacy as being not just knowledge of the concepts and theories of science but also “a knowledge of the common procedures and practices associated
with scientific enquiry” (p.3) to include both procedural and epistemic knowledge. In 2006, PISA also tested students' attitudes towards science through the use of embedded questions and a separate attitudinal measure. In 2015, these sorts of questions will seek information about 'interest in science’ ‘environmental awareness’, both of which have been important foci for governments across Europe.

The TIMSS (Trends in Mathematics and Science Studies) assessment framework will be organised around two "dimensions, content and cognitive” (these are fully elaborated and available at http://timssandpirls.bc.edu/timss2015/frameworks.html).

The cognitive dimension has been structured to include three domains of knowledge, application and reasoning, which have different degrees of attention in the tests for students in years 4 and 8.

Using the PISA and TIMSS frameworks, identify the current thinking about the science curriculum for school students. Summarise the different emphases in both frameworks. Compare both PISA and TIMSS frameworks and reflect on the core similarities and differences.

- What is meant by ‘inquiry’ in these frameworks?
- What sorts of developments in education encourage the use of inquiry in your country / school system? Are these evident in the curriculum, for example?
- How do the priorities in TIMSS and PISA align with the local and / or national approach to science education in your school / country / province?

Now ask the trainees to work in pairs. Provide each pair with a copy of curriculum documents which lay out what should be taught and learned. Ask them to go through these documents to find out which of these, or similar, inquiry competencies is identified in the curriculum and where. Ask them you want them to think about how and when they could/should teach in order to promote these scientific literacy competencies.
Ask them to consider these questions:

- Where are the elements of inquiry?
- How can teaching promote these?

Bring the group back together, and hold a discussion about how IBL can begin to address the curricular demands of science.

Discuss in pairs the following recommendation from the report ‘Science Education in Europe: Critical Reflections’ (Osborne and Dillon, 2008) and draw some conclusions in terms of teaching practices.

“The emphasis in science education before 14 should be on engagement. Evidence would suggest that this is best achieved through opportunities for extended investigative work, and ‘hands-on’ experimentation and not through a stress on the acquisition of canonical concepts”.

Many countries have their own source of research briefings. For example, this site highlighted some of the findings from a research paper on the 2006 PISA data.