Primas

PROMOTING INQUIRY
IN MATHEMATICS AND SCIENCE
EDUCATION ACROSS EUROPE

Guide for professional development providers

Seventh Framework Programme | Theme Science in Society | Support action GA n° 244380
www.primas-project.eu

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PROMOTING INQUIRY
IN MATHEMATICS AND SCIENCE
EDUCATION ACROSS EUROPE

PRIMAS stands for Promoting inquiry in mathematics and science education across Europe. PRIMAS is an international project within the Seventh framework Program of the European Union. Fourteen universities from twelve different countries are working together to further promote the uptake of inquiry-based learning (IBL) in mathematics and science.

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Guide for professional development providers

This PRIMAS guide has been created for third parties who provide professional development for mathematics and science teachers in inquiry-based learning (IBL) pedagogies. The guide outlines our approach and important concepts and principles informed by research that are helpful in designing high-quality professional development actions in IBL. It also introduces core professional development modules which have been developed within the project and are available free of charge on the project website.

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The project PRIMAS -- Promoting Inquiry in Mathematics and Science across Europe (www.primas-project.eu) has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 244380. This publication reflects only the authors' views and European Union is not liable for any use that may be made of the information contained herein.

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Guide for

professional development providers

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1. INTRODUCTION

1.1. About this guide – Aims and purpose

In 2007, the *Rocard report* advocated for a "renewed pedagogy" in the teaching and learning of mathematics and science across Europe. Considering the declining interest of young people towards mathematics and science, but also the need to equip citizens with the necessary competencies for living and working in the 21st century experts are claiming for a teaching of mathematics and science centred on students and organized towards inquiry. "Inquiry based learning" (normally abbreviated as IBL) is the term used widely when referring to this kind of methodologies. In the case of mathematics, "problem based learning" (PBL) is also used[1].

Currently, IBL orientated methodologies are supported in the curriculum of most European countries. However, it is difficult to find them in many classrooms. And this is the situation we are aiming to revert.

In a complex view of the educational systems, there are many tensions, conditions and restrictions that might explain why IBL is not used widely. Among all of them, teachers play a crucial role.

This guide has been written for educators and institutions that provide professional development for mathematics and science teachers. It is the aim of this guide to:

1. State our current understanding about IBL in mathematics and science education, and about teachers' professional development.
2. Introduce a package of resources for teachers' professional development (available at www.primas-project.eu).
3. Offer different portraits of how these materials have been used in different countries to support teachers in their adoption of IBL orientated methodologies.
4. Share some professional development strategies for planning and implementing professional development actions based on PRIMAS materials

You can find extended information and research references in the *extended guide for professional development providers* at the PRIMAS site (www.primas-project.eu).

We expect that the information of this guide offers you inspiring ideas for organizing and successfully implementing professional development activities based on the PRIMAS materials. All together, we will make mathematics and science in school even more encouraging, interesting, meaningful and useful.

[1] In this document, we will used "inquiry based learning" (IBL) to refer both to science and mathematics education.

1.2. About the PRIMAS project

PRIMAS is the acronym of the European project *Promoting Inquiry in Mathematics and Science Education across Europe*. Founded under the 7th Framework Programme, PRIMAS brings together mathematics and science educators from 14 universities in 12 different European countries.

PRIMAS aims to:

- Provide insight into approaches to mathematics and science teaching that are motivational and enjoyable for learners;
- Support teachers with inquiry-based learning (IBL) pedagogies in mathematics and science;
- Provide resources and coordinate professional development for teachers and teacher educators;
- Support teachers, students and parents in their efforts to better understand the nature and importance of inquiry-based learning;
- Develop and work with networks of teachers and professional development providers in participating countries;
- Analyse and understand current policies in relation to inquiry-based learning and inform and work with policy makers to support improved practice.

Our aim is to reach the critical amount of teachers, students, parents and policy makers that will ensure a real and perceivable impact on daily teaching practices, students' learning, parental perception of school mathematics and science, and current and future policies.

Among the different actions PRIMAS is promoting the successful implementation of a wide scale and long-term professional development (PD) programme in every country is absolutely crucial. Teachers are probably the most important actors in promoting a change in the way mathematics and science are conceived and taught across Europe. And together with the support they will get from students, parents and policy makers, they are the only ones capable of making this change really happen.

In order to support teachers in this challenging and fascinating journey, the PRIMAS site offers a wide variety of professional development resources and exemplary classroom materials.

1.3. Inquiry-based learning in mathematics and science education

According to the National Research Council (2000)[2], inquiry in education is '*a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what*

[2] Olson and Loucks-Horsley (2000).

is already known in the light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions; and communicating results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations'.

In a narrow sense, IBL may be defined as a teaching approach which intends to promote learning by engaging students in any of the processes or activities typically involved in scientific research. These include: making observations, formulating hypothesis, defining problems and key guiding questions, designing and performing experiments and communicating results and evidence-based conclusions.

Within the PRIMAS project, there is a multifaceted understanding of IBL which does not only focus on the processes related to scientific inquiry, but on other key aspects considered essential for an efficient IBL implementation. These characteristic IBL features are briefly outlined below:

Student activity

Inquiry based learning is a student-centred methodology which stresses the importance of the active construction of learning. Therefore, students are expected to pose questions, make decisions, design plans and experiments, discuss, collaborate, communicate results and provide justified answers and explanations when engaged in the inquiry process.

The teacher's role

Teachers are not considered as knowledge providers, but as motivators and facilitators of students' learning. For this purpose, specific teaching competences are required to subtly guide students and help them work in profitable ways. The use of questioning is one of the key teaching competences in inquiry methods. Appropriate questions can enhance students' reflection, critical and logical thinking and self-regulation. To this end, the ability to prompt constructive interaction between students when holding a discussion is crucial for ensuring the social construction of knowledge. Teachers should also know how to design and use unstructured tasks which offer appropriate challenges and provide rich contexts and scenarios to facilitate learning.

The classroom atmosphere

The classroom atmosphere is considered to be a key feature in the efficient implementation of IBL. It is important to establish a culture where there is not a knowledgeable authority but instead ideas are respected and accepted according to their foundation and how they are supported by evidence and logical thinking. In this atmosphere, mistakes are considered to be learning opportunities and there is a shared sense of ownership and purpose.

The expected learning outcomes

Students are expected not only to acquire conceptual understanding of science topics and mathematical tools, but also to develop process skills and competences. Since IBL requires a student-centred approach it encourages autonomous and life-long learning.

PRIMAS considers IBL as an essential ingredient to successful education. The following diagram shows five key aspects of IBL and highlights specific features that are characteristic of each perspective (Figure 1).

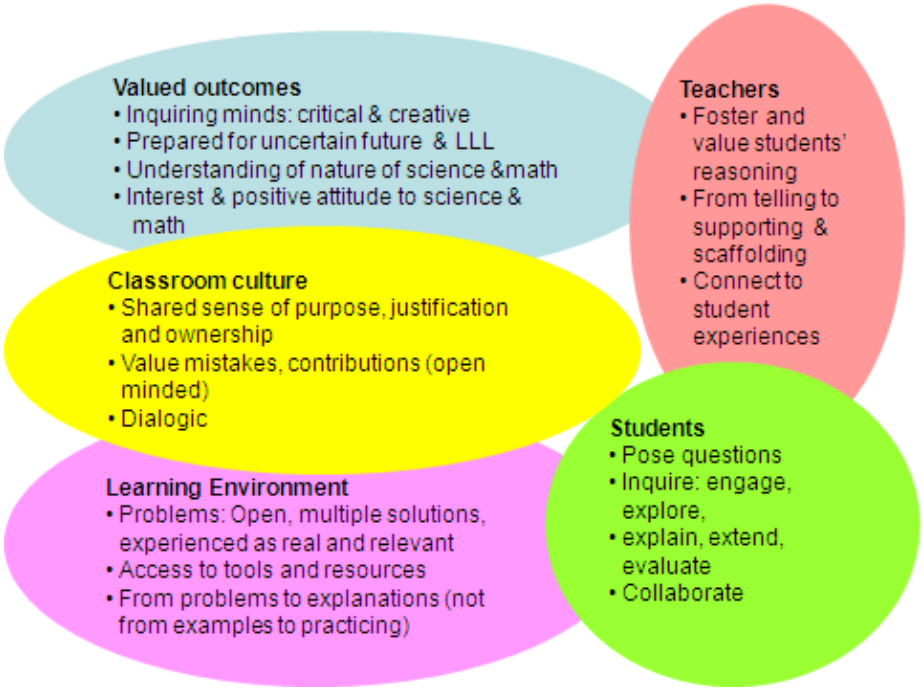

Figure 1. Multifaceted understanding of IBL

1.4. The professional development of teachers

Teachers' professional knowledge is difficult to model. It includes knowledge about the subject they teach (mathematics or science), about how students learn, and about how the teaching should be organized. But it is more than this; it also includes their epistemological conception about the subject they teach, their beliefs about teaching and students' learning, about school and its role in society and many more issues.

Teachers' professional knowledge can be seen as the outcome of all the different experiences they have been involved in. Some of them *formal* like their initial training and the professional development activities in which they have participated. Other experiences are rather *informal,* like when having learnt mathematics and science as students or the information about mathematics, science and its teaching received through different media

(magazines, scientific papers, professional journals…), their daily experiences when teaching mathematics or science, and so on.

A simplistic view of teachers' professional learning considers that the teachers' lack of knowledge (about their subjects, about the teaching and/or learning of their subjects) can be *repaired* by direct instruction. According to this view, and considering that many teachers might lack in professional knowledge needed for an IBL orientated teaching of mathematics and science, it should be enough to design and implement training courses based on the transmission of the information they lack.

Transmissive professional development is an economical strategy for transferring information to teachers about new pedagogies, materials, curriculum, etc. However, it is normally off-site and, due to its lack of connection to the current classroom context in which participants work, its capacity to transform teachers' practices is quite limited (Kennedy, 2005). To some extent, *transmissive training* simulates traditional approaches in the teaching of mathematics and science, in which teachers (or trainers) explain, and students (or teachers) are passive receivers of information.

Nowadays, teachers are conceptualized as professionals that make their pedagogical practice evolve, as the result of processes like analysing the current state of their practice, reflecting about their teaching practices and students' outcomes, experimenting new approaches, and reflecting again about the strength and the limitations of those approaches. And all of them in social settings, because teachers' professional learning is enhanced when opportunities for discussing and exchanging ideas are offered. Ideally, this process can be visualized as a spiral, capturing the fact that teachers' professional knowledge is expanding and growing (Figure 2).

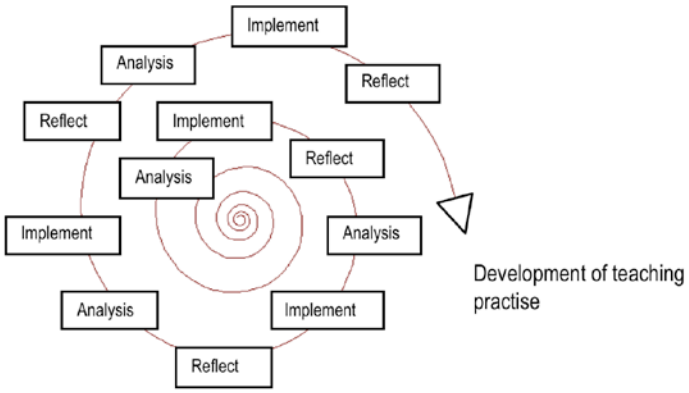

Figure 2. Spiral model of teachers' professional development

This has clear implications for the design of teachers' professional development materials and actions. They need to be designed in a way that teachers' reflection about their practice is encouraged, the use of new methods is promoted, and discussions as well as the exchange

of experiences and ideas are enhanced. Because always-working recipes do not exist in education, professional development activities should offer teachers rich-learning opportunities for questioning their current practices and make them evolve. They should be based on solid knowledge coming from research, but also opened to adaptation and customization.

For instance, instead of lecturing teachers about *effective questioning* and how it should be used to promote students' inquiry, professional development activities should encourage teacher to reflect on the kind of questions they use and the consequences these questions have on their students' learning. Next, they could reflect about how questioning might be used to support students' inquiry processes. Some research evidence about how using questioning effectively could be provided. Afterwards, they should have the opportunity to plan and implement an IBL-orientated lesson in which they pay special attention to the kind of questions they are using whilst monitoring the lesson. Finally, they should have the opportunity to share and reflect about others' experiences. At the end of this professional learning trajectory each teacher will have developed their own understanding about the role of questioning in IBL-oriented classrooms, and her professional knowledge has been expanded. And this is an on-going and discontinuous process. As long as one continues analysing, experimenting and reflecting, their *questioning abilities* will continue improving and growing.

1.5. The education of multipliers

PRIMAS is facing the challenge of a widespread dissemination of IBL, which means working beyond the local scenario. Scaling-up professional development is still an open problem (Adler and Jaworski, 2009; Loucks-Horsley et al., 2003), going beyond the need of attracting more teachers. Issues like robustness, flexibility, and quality assurance are also important.

A well-known scaling-up strategy is the so-called "cascade model". Basically a structure in which a little group of educators work with a larger group of prospective ones, which become educators for a wider group later, and so on. However, the problem of what qualifies someone to be a teacher educator, and how this qualification should be structured, still remains.

Within the PRIMAS project, a specific model for scaling-up professional development, based on the education of multipliers, was developed (based on Müller, 2003, see also Maass and Doorman, 2013). This model is structured in three strands:

1. "Learning-off-job": basic qualification of multipliers through seminars tailored to the needs of participants. In these seminars, prospective teacher educators will find opportunities to learn and reflect about IBL, about teacher professional development and about PRIMAS modules and materials. There is no unique way of organizing these seminars. Indeed, different contexts might need different structures. However, all of them should reflect the professional development principles underneath PRIMAS materials.

2. “Learning-by-job”: multipliers being supported by colleagues or experienced teachers educators when running professional development courses. Different strategies can be used: meetings to discuss and reflect about their professional development courses; supervision among teacher educators; observation of others’ professional development courses, which in turn give feedback.
3. “Learning-in-job”: multipliers’ self-education. As life-long learners, multipliers’ competencies will grow based on their experiences. Practical problems they have to face when running professional development courses, reflection on their practice, the literature and resources they have access to, and so on. In contrast to strand 1, this last one is less structured and difficult to monitor.

2. GUIDELINES FOR PROFESSIONAL DEVELOPMENT PROVIDERS BASED ON PRIMAS MATERIALS

It is the aim of this section to:

- Explain the how the PRIMAS professional development package is designed, uncovering the hypothesis about teachers' learning behind it.
- Describe the main contents of each module.
- Introduce some guidelines for planning PD actions based on PRIMAS materials.
- Offer different portraits of how PRIMAS has been implemented in different countries.

2.1. Conceptualizing PRIMAS professional development

PRIMAS is not aiming at replacing existing curricula and teaching practices. It is our aim to enrich teachers' teaching repertoire, so that they can offer enriched learning opportunities to their students. Specifically, learning opportunities in which students can inquiry in meaningful situations, developing both disciplinary knowledge (in mathematics and science) and inquiry skills (like observing systematically, experimenting, hypothesising, controlling variables, arguing, or communicating).

In every teaching situation there is a distribution of responsibilities between the teacher and their students. According to Anderson (2002), in a *traditional teaching situation*, teachers act as *dispensers of knowledge*, whilst students act as *passive receivers*. In these settings, teachers transmit information, direct students' actions and explain conceptual relationships, while students are supposed to record teacher's information, memorize it and follow the teachers' directions. Normally, students' work is about completing worksheets, containing the same tasks for all of them.

Most of the teachers feel confident in this kind of teaching situations, and have developed professional skills to deal with them. They can rely on textbooks, which have been designed to assist them in delivering this kind of teaching.

IBL places both teachers and students in a different scenario, where there is a different distribution of responsibilities. In contrast with the "transmission approach", teachers now become *coaches and facilitators*. Their role is more about helping students to process information, coaching students' actions, facilitating students' thinking, and modelling students' learning process. For their part, it is students' role to process information, to interpret, explain and hypothesize, and to share authority for the answers they formulate. Consequently, students' work is more self-directed. There might be different tasks among students; even students could design and direct their own tasks. Students' reasoning,

reading and writing for meaning, solving problems, building from existing cognitive structures, and explaining complex problems should be emphasized (Anderson, 2002).

For many teachers, this is a new scenario. For others, it is an already known one, but rarely explored. Most feel that their professional skills are not appropriate to deal with the challenge of an IBL orientated teaching. This explains, at least partially, why many of them are so reluctant to include this kind of activities in their classrooms.

Considering that teachers are not starting from zero, the main hypothesis of PRIMAS professional development programme is that teachers will enrich their teaching repertoire in cycles of analysis-planning-implementation-reflection, in IBL scenarios. Specifically:

1. Firstly, teachers are invited to reflect on the contexts in which they work, expressing their opinions about the discipline and subject matter they teach and how they think it must be worked on at school. They are also encouraged to describe their current classroom practices and share their beliefs about teaching and learning processes. The main purpose is starting to build on teachers' initial beliefs and practices and set up the basis for future reflection.
2. Secondly, teachers are provided with classroom tasks and contrasting practices which they have to analyse. Videos showing their use in the classroom make it easier to compare teachers' existing practices and experiences with different ones, promoting reflection on IBL implementation. The main purpose is to challenge teachers' practices and to offer a vicarious experience on IBL successful use, in day-to-day teaching.
3. Thirdly, teachers are encouraged to use IBL tasks in their own classrooms.
4. Fourthly, teachers meet together to share their classroom experiences, discuss the pedagogical implications and reflect on the growth of new practices and beliefs. This process is repeated, cyclically, with new pedagogical challenges presented at each meeting.
5. Teachers are also invited to create their own tasks and provide professional development for colleagues within their own schools, as well as building a learning community among all the teachers involved. Continuous follow-up and support is provided by the PRIMAS team.

There are many challenges teachers have to face when implementing IBL activities. PRIMAS materials cover some of the, in the so-called PRIMAS modules (Figure 3).

Figure 3. Professional development modules

Each module includes:

- A detailed guide for professional development providers. This guide explains how to run professional development sessions based on each module, teachers' activities and background information.
- Teachers' hand-outs, with the activities teachers will be doing within the professional development sessions, and key information on pedagogies for an IBL orientated teaching.
- Different versions and adaptations of the activities for mathematics teachers and science teachers.

In the next subsection, we will introduce the contents of each module, which are available at the PRIMAS site (Figure 4).

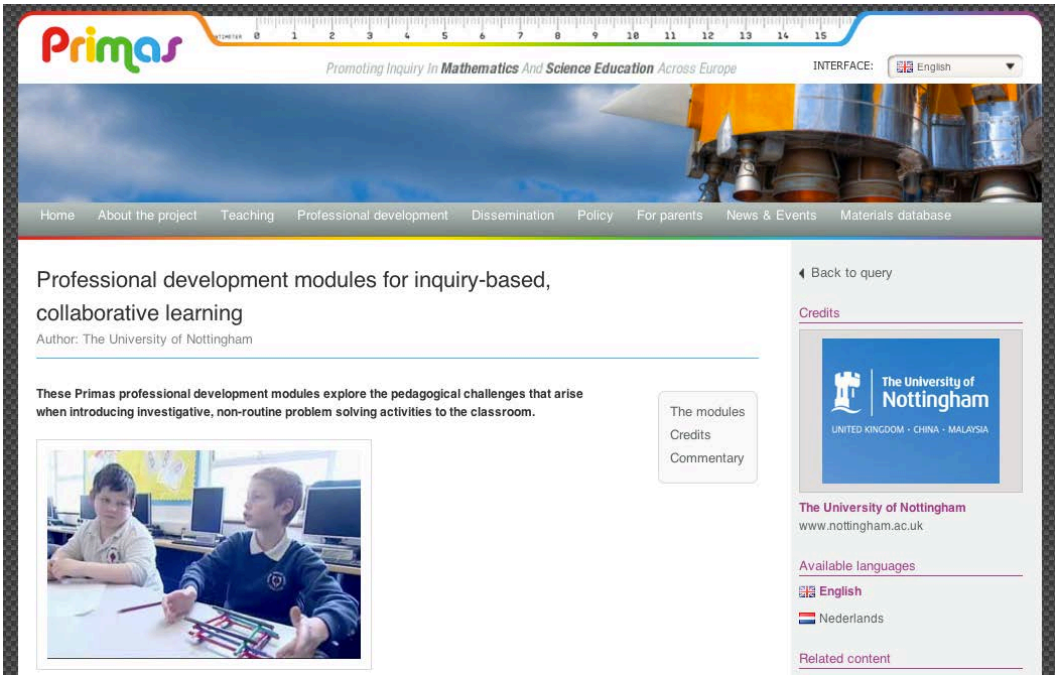

Figure 4. PRIMAS website: Professional development modules

2.2. PRIMAS professional development modules

PRIMAS modules deal with those critical issues, teachers will find when implementing IBL-orientated activities in their classrooms. They neither do pretend to cover all problems teachers might face when running an IBL activity with their students, nor to offer the best and unique solutions.

Seven modules have been designed. They include several activities and resources that allow teachers to analyse and reflect on their current practices, and to make them evolve. Although the modules include clear guidelines, they are not a collection of recipes. Teachers will elaborate their own strategies to deal with IBL-orientated teaching situations as a combination of their current knowledge, beliefs and attitudes, the outcomes of the professional learning activities included on each module, their experiences when implementing IBL activities with their students, and reflection on their experiences and the experiences of their colleagues (according to the *spiral model in* Fig. 1).

Any planned professional development programme should offer opportunities for teachers to take risks and try new pedagogies in the classroom and then report back and reflect on their experiences. Each module includes an activity in which teachers have to plan a lesson, teach it and reflect on the outcomes. This kind of activities is therefore essential in the programme and should not be missed!

2.2.1. PD module 1: student-led inquiry

At its most fundamental, inquiry-based learning is about engaging students' curiosity in the world and the ideas that surround them. As scientists and mathematicians, they observe and pose 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 analysing data, making representations, and by making connections with what they already know. They try to interpret their findings, check that they are accurate and sensible and then share their findings with others.

This process is often missing in the school classroom. There, the teachers usually points out what has to be observed, they provides the questions, demonstrate the methods to be used and check the results. Students are merely asked to follow the instructions.

In this module, teachers will be encouraged to experience what it feels like to think like a mathematician or scientist, and reflect on the role shifts that are necessary for students to share this experience in the classroom. Teachers are shown phenomena and situations and are invited to pose and pursue their own questions. This experience is then transferred to the classroom.

2.2.2. PD module 2: tackling unstructured problems

In most mathematics and science classrooms, students are provided with structured tasks and are precisely told 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. This unit compares structured and unstructured versions of problems and considers the demands and challenges unstructured problems present to students and teachers.

2.2.3. PD module 3: Learning concepts through inquiry

This unit considers how the processes of inquiry-based learning may be integrated into the teaching of Mathematics and Science content. Often, these two aspects of learning are kept separate: we teach content as a collection of facts and skills to be imitated and mastered, and/or we teach process skills through investigations which do not develop incorporate important content knowledge. The integration of content and process raises many pedagogical challenges.

Here, the considered processes 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 before, 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 unit has many activities within it - too many for one session. It is suggested that this unit is used as a menu, from which professional development providers can choose. However, it is important that participants are given an opportunity to try out some of these activities in their lessons and to report back on the outcomes.

2.2.4. PD module 4: Asking questions that promote IBL

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

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

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

2.2.5. PD module 5: Students working collaboratively

If students are to make sense of scientific and mathematical concepts, then they will need opportunities to share, discuss and work together. Research has shown that cooperative small group work has positive effects on learning, but that this is dependent on the existence of shared goals for the group and individual accountability for the attainment of these goals. It has also been seen to have a positive effect on social skills and self-esteem (Askew & Wiliam, 1995).

In many classrooms, however, traditional transmission teaching styles have reduced both the quantity and quality of student-student discussion. In others, students do work and talk together, but this talk does not always profit learning.

This unit is designed to offer the professional development provider some resources that will help teachers to:

- consider the characteristics of student-student discussion that benefit learning;
- recognise and face their own worries about introducing collaborative discussion;
- explore techniques for promoting effective student-student discussion;
- consider their own role in managing student-student discussion;
- plan discussion based lessons.

The module includes a set of activities for teachers' professional learning. They are presented in a logical order, building up knowledge and expertise. For any planned professional development programme it is important to offer opportunities for teachers to take risks and try new pedagogies, report back and reflect on their experiences. Consequently, "activity G" in this module should not be missed.

2.2.6. PD module 6: Building on what students already know

Inquiry-based teaching assumes that students do not arrive at sessions as 'blank slates', but as actively thinking people with a wide variety of skills and conceptions. Research shows that teaching is more effective when it assesses and uses prior learning so that the teaching may be adapted to the needs of students (Black & Wiliam, 1998). Prior learning may be uncovered through any activity that offers students opportunities to express their understanding and reasoning. It does not require more testing. For example, it can take the form of a single written question given at the beginning of a session to elicit a range of explanations that may then be discussed. This process, often referred to as formative assessment, may be defined as:

"... all those activities undertaken by teachers, and by their students in assessing themselves, which provide information to be used as feedback to modify the teaching and learning activities in which they are engaged. Such assessment becomes 'formative assessment' when the evidence is actually used to adapt the teaching work to meet the needs." (Black & Wiliam, 1998, p. 91)

This module considers the different ways this can be done and focuses on the following questions:

- How can problems be used to assess performance?
- How can this assessment be used to promote learning?
- Which kinds of feedback are most helpful for students and which are unhelpful?
- How can students become engaged in the assessment process?

2.2.7. PD module 7: Self and peer assessment

According to Black and William (1998):

"... self-assessment by students, far from being a luxury, is in fact an essential component of formative assessment. Where anyone is trying to learn, feedback about their efforts has three elements—the desired goal, the evidence about their present position, and some understanding of a way to close the gap between the two. All three must to a degree be understood by anyone before they can take action to improve their learning."

This is particularly true when the focus of the assessment is on the processes involved in IBL. Many students do not understand their nature and importance in mathematics. If a student's goal is only to get 'the right answer', then he or she will not attend to the deeper purposes of the lesson.

This module encourages discussion of the following issues:

- How can we help students to become more aware of IBL processes, and their importance in problem solving?
- How can we encourage students to take more responsibility for their own learning in IBL processes?
- How can students be encouraged to assess and improve each other's work?

2.3. Planning your professional development activities

PRIMAS is offering a professional development package, together with extra resources for the classroom (PRIMAS database). From the very beginning, both have been designed considering some general principles about teachers' learning (section 2.1). When planning your professional development activities this information will be useful. However, you can use different professional development strategies[3] and you can also use PRIMAS modules in several different ways.

According to the existing literature[4] on teachers' professional development, key factors for success (among others) are teachers' autonomy and students' outcomes. That is:

- The more autonomy teachers have to decide on the contents and structure of the professional development activities, the more impact this will have in their practices.
- The bigger the teachers' perceived impact of new methodologies on students' learning is, the more likely it is that they want to continue trying this new approaches and experimenting within their classrooms.

However, it might happen that, initially, teachers might need closer guidance (for instance, because they know almost nothing about IBL, or because of their professional development cultures). Also, improved students' learning might not be perceived in a short period of time.

As a provider of professional development for teachers, you can use PRIMAS resources in many different ways, combined with different professional development strategies. We would like to draw your attention towards two ideal ways of doing so:

- Guided professional development actions
- Self-regulated professional development actions

2.3.1. Guided PD actions

A first option you might consider when planning your PD activities could be in form of a guided intervention. That is, teachers as a community of learners collaborating together in face-to-face sessions monitored by one or several *facilitators* (*educators, trainers*). This is recommended for teachers who are not familiar with IBL and/or with self-regulated professional development.

Considering the design principles behind the PRIMAS modules, the face-to-face sessions should not be considered as the place where the teachers will be told about IBL-orientated teaching (transmissive professional development). On the contrary, those will be the opportunities where teachers will reflect on the characteristics of an IBL-oriented teaching, about the difficulties and obstacles they might face, and, of course, where their current beliefs and teaching techniques will be challenged.

[3] More information about teachers' professional development strategies can be found in the longer version of this guide, available at the PRIMAS site.

[4] Loucks-Horsley et al., 2003; Back et al., 2009.

Teachers' work within these face-to-face sessions will be articulated around PRIMAS modules. As explained before, these modules offer a rich variety of professional development activities centred on key aspects of teaching through inquiry. The expected outcome will be teachers' best understanding of IBL-oriented teaching and a widened repertoire of teaching techniques to deal with IBL situations.

PRIMAS modules could be used flexibly. However, you might find the following suggestions interesting (Figure 5.):

i. Start with PD module 1 (*student-led inquiry*). Teachers will have the opportunity to work on some IBL activities and to experience them in the position of learners. They will be invited to uncover their current understanding about IBL. The module includes two different classroom videos offering a first insight on how an IBL-oriented classroom might look like. From the debate, some key features could emerge (like dealing with open-ended problems, supporting students whilst working in groups, teaching concepts, or assessment) that will be tackled later on. Somehow, it allows teachers to start posing questions about IBL before these will be answered (at least, partially) in the next sessions.
ii. Next, you can decide about the module you would like to use, considering your local context and teachers' interest. However, PD module 2 (*tackling unstructured problems*) might be a good continuation. Whilst reflecting about closed and determined situations versus open and undetermined ones, teachers will find new opportunities to think about their current pedagogies and those that support students' learning in inquiry scenarios.
iii. In the following sessions, you can decide whether you prefer working on the development of concepts through inquiry processes (PD module 3) or in ways of supporting students' when working together (PD modules 4 and 5). In the case you opt for the later one, our suggestion is that you use module 4 first (*effective questioning*), and then module 5 (*collaborative work*). A reason for this choice is that module 4 will give teachers important guidelines for supporting students while working collaboratively.
iv. Finally, you can use modules 6 and 7, centred on formative assessment. In this case, it is suggested that you use module 6 (*building on what students already know*) before module 7 (*self and peer assessment*).

Figure 5. Guided PD actions: using PRIMAS modules

Face-to-face sessions need to be enriched with teachers' experiences when implementing IBL activities with their students. That means that you have to take into account that teachers need time to plan their intervention, teach the lesson and reflect on the outcomes. Besides, this process has to be repeated several times. As a consequence, it is highly recommended that you distribute face-to-face sessions over a long period of time (several months), leaving teachers enough time for the implementation face (Figure 6). Also that you plan carefully teachers' work between the sessions, with the help of the suggestions given in each module, and that you consider teachers' work as the starting point for the next session.

Face-to-face session	*Plan, teach and reflect*	*Face-to-face session*	*Plan, teach and reflect*	*Face-to-face session*	*Plan, teach and reflect*	*Face-to-face session*	.....

Figure 6. Guided PD activities: distribution of sessions

This structure is given as an orientation. Considering the time you have for each session, teachers' background, and also the professional development activities you would like to do with them, you could find interesting, for instance, to carry out two face-to-face sessions in the same week, and then a *planning-teaching-reflecting* period.

At the end of a professional development intervention like this, teachers will have become familiar with IBL, they will have enriched their teaching repertoire, as well as developed new competencies for teaching though inquiry. This *guided action* might approximately last for one school-year, and could be followed by a more self-regulated period (see section 2.3.2).

2.3.2. Self-regulated PD actions

In a self-regulated PD programme, teachers work as a *community of inquiry*. They:

- decide about the professional problems they will work on,
- inquiry about possible strategies to deal with them,
- design, conduct and analyse their interventions with their students (experimental phase)
- learn from each other and from their practice, making their professional knowledge grow.

Somehow, they reflect the dynamic of an inquiry-based learning scenario. But now the knowledge at stake is not mathematics or science, but pedagogical and professional knowledge.

A first requisite for a PD like this is that teachers are more or less familiar with IBL, and also with self-regulated and autonomous professional learning. The guidance of an expert might be important, although not absolutely necessary. Several approaches might be followed; some of them more or less sophisticated like *lesson study* or *action research* (there is more information about professional development strategies in the long version of this guide, available at the PRIMAS site).

In a self-regulated PD programme, PRIMAS modules could have a role to play. They might be used as the driving force for the group. As each module tackles critical aspects of teaching through inquiry, offering valuable insights and suggestions, they could be used in the inquiry process in many different ways. For instance:

- The group could study and critically analyse each module, offering possible alternatives.
- The group could choose one or several modules and plan a classroom intervention following them. Later, the experimental phase might be the source for a deeper debate on the associated pedagogies.

In contrast with a quasi-linear structure of the “guided intervention”, now it does not make sense to give a progression in the use of the modules. It might happen that the group uses only a few of them. Moreover, it is expected that teachers enrich and expand the modules, also that they bring other aspects of IBL into the group, which were not explicitly considered before (Figure 7).

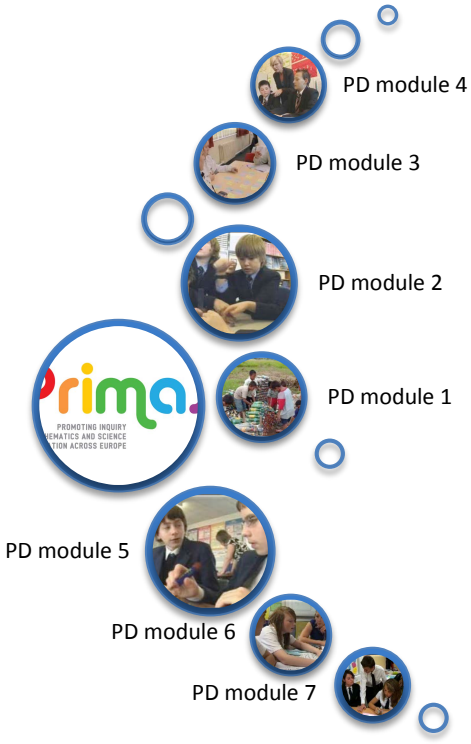

Figure 7. Non-linear structure of PRIMAS modules in a self-regulated PD intervention

This kind of professional development intervention might be considered as the continuation of a *guided* phase, for instance, in a second year. Now, teachers can deepen into those aspects related with IBL that they find more interesting or challenging, like incorporating IBL activities regularly in their teaching whilst developing the intended curriculum, designing IBL tasks, or inquiring about specific students' inquiry processes.

3. CASES: PRIMAS PD IN DIFFERENT COUNTRIES

Finally, in this section we will exemplify how professional development actions, based on PRIMAS materials, have been designed and implemented in some countries.

In most of these cases, a two-step PD process has been used because in most of the PRIMAS countries a *cascade model* was followed: (1) working with experienced teachers and/or trainers that will act as *facilitators*; (2) these *facilitators* working with teachers.

In the first step, a more *self-regulated schema* has been followed, due to the fact that teachers/trainers had some experience on IBL, also on professional development. On the contrary, the second step has been organized following a *guided schema*. Anyway, "guided" and "self-regulated" schemas, as explained before, could be considered as ideal cases. As you will see through the particular cases in this section, there is a vast territory in between.

In section 2.4.1., we will focus on the education of multipliers, while section 2.4.2 will be devoted to the professional development of teachers.

3.1. The education of multipliers

3.1.1. Case 1 - The education of multipliers in Spain: a short "learning-off-job" phase followed by a "learning-by-job" period.

In Spain, the implementation of PRIMAS has been articulated through a special institution called the Teachers Centres. They depend on the Regional Ministry of Education in Andalucía and are in charge of providing accredited professional development for teachers.

The PRIMAS national team contacted the directors of these centres, with the mediation of the Regional Ministry of Education. Those centres interested in PRIMAS selected prospective educators among experienced teachers. Altogether, almost 100 experienced teachers, some of them also with experience in professional development, were initially involved in autumn 2011.

The education of these multipliers had been conceived as a short "learning off-job" phase followed by a "learning by-job" period. The reason for this choice was to make prospective educators familiar with PRIMAS philosophy and professional development in the short phase and, thereon, let them work collaboratively on the real design of the professional development actions they will run later on with teachers. There were also external constraints that led to this organization, like the limited availability of the national PRIMAS team to attend all the Teachers Centres.

The "learning-off-job" phase resulted in three face-to-face sessions, facilitated by the PRIMAS national team:

- The aim of the first session was to uncover prospective educators' understanding about IBL and to get to a common starting point. They were invited to explore some IBL tasks (both in mathematics and science) and, from them, to sketch a possible definition of IBL. The debates afterwards, based on their definition, lead to a common initial understanding of the meaning of IBL.

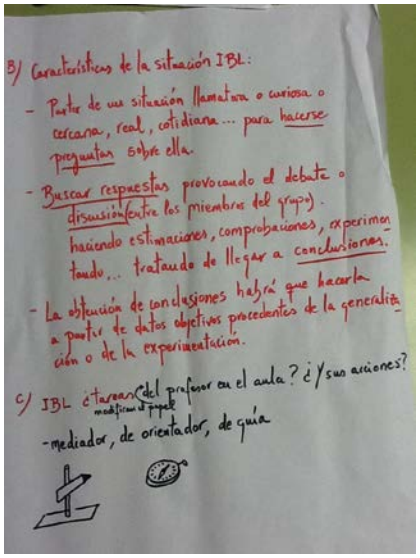

Figure 8. Session 1 in Almería, uncovering current understanding about IBL

- The second session was structured around the PRIMAS modules. Prospective educators were grouped at the end of the first session and received one module. In the days between session 1 and 2, they had to critically analyse their module, and to think about issues they would like to add, change or remove. During the second session, they had to explain their module briefly to the rest of the group, including their personal valorisation and changes. At the end of this session, all the teachers were familiar with the modules and their aims.

Figure 9. Session 2 in Jerez, working on the PRIMAS PD modules

- In the third session, prospective educators worked in groups. They had to plan how they would work with teachers in the future. Considering that the second step (with teachers) would be organized following a guided scheme, they had to decide on which modules they are likely to use, in which order they would implement them, decide on extra activities or materials they would like to use, name the number of face-to-face session, explain how to structure and monitor the work of teachers in the periods between the sessions, etc.

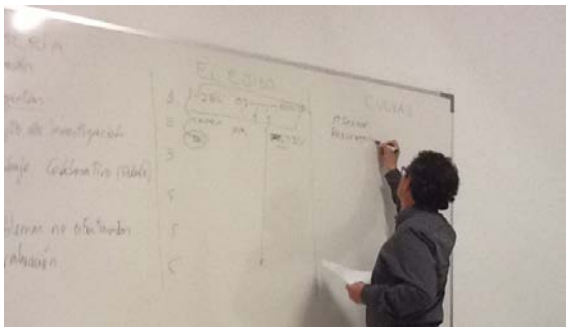

Figure 10. Session 3 in Almería, planning PD course based on PRIMAS modules

Obviously, planning a whole PD intervention is a hard and long task, impossible to fulfil in one session. The aim of this session was to start the planning process, facilitating the transition between the "learning-off-job" phase and the "learning-by-job" period.

In this second phase, groups of prospective educators were working autonomously for approximately two months. In this self-regulated work, they went back to the modules several times, adapted activities, and introduced new ones. Even some of them implemented IBL activities with their own students in order to get a deeper insight, some of which were videotaped and analysed. Technically, this period should have ended when the PD courses for teachers started. However, two different cases occurred:

1. Some groups felt really confident about their capacity to run PD activities based on the PRIMAS materials. They felt comfortable with the PD materials and familiar with IBL pedagogies. Some of them even included extra materials and activities of their own. The "learning-by-job" phase was primarily focused on organizational issues and resulted in PD actions within a relatively short period of time. After this phase, professional development courses were organized, where they act as facilitators.
2. On the contrary, other groups felt insecure about their own capacity to run PD activities. They needed a deeper reflection about IBL, also a deeper understanding of the PRIMAS PD modules. The "learning-by-job" period in these groups was structured around study seminars, focusing on the PRIMAS modules. Besides, in some cases prospective educators implemented IBL activities with their students and visited each

other in order to gain first quality experience. These groups had new face-to-face session with the PRIMAS national team (1-2 extra sessions) from which they got extra support. In contrast with the "learning-by-job" period of the first groups, now this phase lasted more than 2 months. In most of the cases, it lasted around 5-6 months. Finally, the work of some of these groups led to the planning and implementation of professional development actions whilst, in other groups, this phase resulted in a self-learning period with no further implications in terms of running professional development for other teachers.

Finally, those educators who were involved as facilitators in PRIMAS PD actions continued their professional learning whilst running PD session with teachers, in a third phase that could be seen as a "learning-on-job" period.

3.1.2. Case 2 - The education of multipliers in Germany: an extended "learning-off-job" period.

In Germany, all professional development courses were held by multipliers. These multipliers are normal teachers with almost no experience in teacher training and thus they are especially trained within PRIMAS.

In order to win teachers to work as multipliers the German team contacted the ministry of culture, youth and sports of Baden-Württemberg and the regional school authority. The ministry supported the multipliers by offering one hour reduction in teaching for the multipliers and the regional school authority sent the information about being a multiplier to all schools (primary and secondary schools). Altogether, 26 teachers applied for working as a multiplier.

Figure 11. Education of multipliers in Germany

The German model of educating multipliers follows the model described above with the three strands: Learning-off-job, learning-by-job and learning-on-job (see section 1.5.)

The training of the 26 multipliers began one year before they started running courses themselves with five days spread over the year 2011 (Learning-off-job). Their own work as multipliers started at the beginning of 2012 and will end in 2013.

While working as a multiplier, they got three days of further training in 2012 and will get up to three further trainings in 2013, which will lead to six days of training while they work as multipliers (Learning-off-job).

Additionally, their work as multipliers will be studied by the PRIMAS-Team by sitting in courses and giving advice (Learning-by-job).

The multipliers work in pairs or groups of three (learning-by-job) and train from 5 to 18 teachers. Multipliers meet their groups around four afternoons a year. Additionally, two big events will be held which will bring all multipliers, their teachers and the PRIMAS team together as to exchange experiences.

From year three on, they will get further advice on self-education (Learning-on-job).

In the learning-off-job phases we used the 7 modules given by the international project as described in section 2.2. Furthermore, the multipliers were asked about what topics they would like to work on in each session, in order to both implement inquiry-based learning and to run their professional development courses. So, in addition to the seven modules as described above, the following topics were dealt with in order to start off from the multipliers needs:

(1) How to enhance students' inquiry competences.

(2) How to assess written class tests.

(3) Inquiry-based use of experiments in sciences.

(4) How to work with parents.

(5) Beliefs: What do you consider as effective mathematics teaching?

(6) How to prepare a course of professional development.

(7) Dealing with heterogeneity of students.

(8) Preparing inquiry-based teaching units.

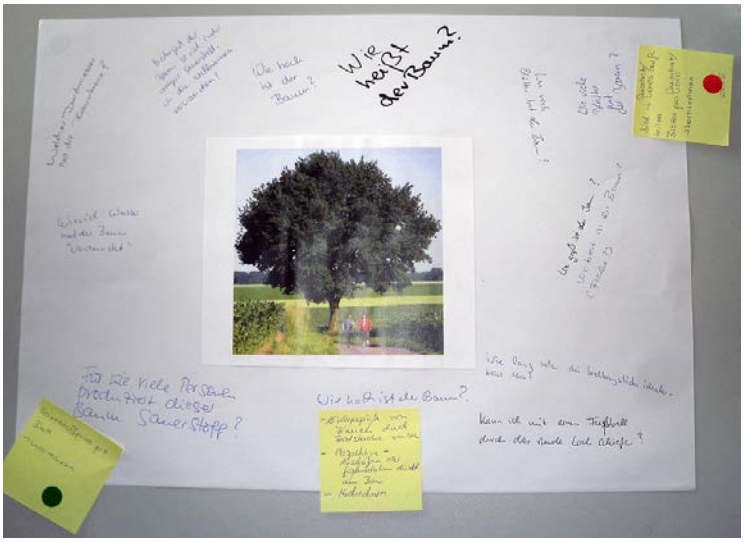

Figure 12. Working result of the task: “Asking questions” from PD module 4

Subsequently, the resulting education of multipliers was a mixture of what the project team considered as important and of the multipliers needs.

In all meetings with the multipliers reflection on a meta-level played a crucial role. The multipliers reflected on how to use the modules in their courses, what problems may arise and how to prepare teacher training sessions. Additionally, professional development sessions were simulated.

Finally, we also established a “critical 10-minute talk” to get the feedback from the multipliers and ask for their wishes and needs. This is also supposed to be an encouragement for the multipliers to establish such a talk in their professional development courses as to be able to react to teacher’s needs.

Before their first own professional development the multipliers, most of those who have had no experiences in running professional development courses were quite nervous. After this first time, we received the feedback that they felt well prepared for their job as multipliers. Further, they felt that relevant topics are dealt with in our multiplier education. Our visits of the professional development courses held by multipliers showed a good quality of the courses, although there is of course a certain potential of optimization. So, in some first sessions the multipliers for example did not talk about the aims of inquiry-based learning.

The German professional development courses held by our multipliers will run for 2 years starting in February 2012 and ending in December 2013. Altogether, about 100 teachers are participating in the German PRIMAS courses.

3.1.3. Case 3 - The education of multipliers in Norway: a long-term “learning-off-job” period, followed by “learning-by-job” and “learning-in-job” phases.

In Norway, the education of multipliers was conceived as a long “learning-off-job” phase, followed by a mixture of “learning-by-job” and “learning-in-job” phase. Hence, the education of multipliers was conducted over an extended period of time.It lasted for 18 months.

Figure 13. Multipliers in Norway

Initially, a group of 24 teachers worked together, starting in February 2011 with a team of teachers from different schools with each school sending about 3-5 teachers. Over the eight subsequent sessions (mainly whole-day sessions) several teachers dropped out, and others joined the group. Finally, there were approximately 14 ‘regulars’- these teachers were determined and motivated to work as ‘multipliers’ (facilitators, step 2).

Figure 14. Multipliers in Norway

Over 18 months, the Norwegian PRIMAS team worked with these teachers in terms of IBL; formative assessment (e.g. questioning; feedback on pupils' written work, etc.); analysis/amendment of mathematics and science tasks to keep/build up cognitive demand, to name but a few of the themes covered. Each session was evaluated by the participating teachers with a qualitative evaluation form developed by the Norwegian team.

In one of the last sessions the PRIMAS team worked with teachers on the different module hand-outs: teachers chose from the PRIMAS modules which they found most valuable, and they changed and amended existing PRIMAS modules. The team also developed selected additional modules for Norwegian teachers (e.g. task analysis module/section; work with/analysis of video for professional development/ developing the art of 'noticing').

With the help of the district officials (responsible for teaching/learning in local schools) and an active link-teacher (in charge of organising link-activities and cross-school professional development sessions), the PRIMAS national team developed an online platform where teachers could talk to each other and where materials were hosted (within the learning management system "It's Learning", see www.itslearning.com). Although difficult at start and with the help of the district officials, the team managed to convince school principals and to organise a system of how teachers could work with colleagues of other schools. This provided a lot of 'cross-fertilisation' of ideas and experiences.

During the first six (to twelve) months of multipliers working with colleagues, they were supported by experienced teacher educators, which can be described as an example of the "learning-by-job" model. At the same time multipliers also worked by themselves, or with colleagues in the same school, hence according to the "learning-in-job" model.

During this time case study data were collected to follow the multipliers' progress, as it is known from research (e.g. Koellner et al. 2008) that novice multipliers (or instructional leaders) find the early sessions as instructional leader a challenging time, and they need 'appropriate' support. It was interesting that the PRIMAS multiplier teachers also supported each other, as always two (or more) teachers worked as multipliers in schools. And they supported each other as a group, with the link-teacher acting as the connection between the school groups. Most of the multipliers were very keen to keep up the PRIMAS group as their 'space' for professional development.

3.1.4. Case 4 - The education of multipliers in Switzerland: creating a common culture through a long-term process combining "learning-off-job" and "by-job".

In the education of multipliers phase, 20 professional trainers (some of them working at the university, others working as teachers, covering all the school levels) have been working for 2 years. They have met once a moth in 2h sessions, plus 5 whole day sessions, combining "learning-of-job" phases with "learning-by-job" ones.

Due to the diversity of participants (considering both, the variety in school subjects and the level of schools, primary, lower or upper secondary), most of the first months' work was

dedicated in exchanging and creating a basis for a common culture. They examined several teaching materials. They also developed some didactical tools to analyse teachers' practices regarding IBL activities. They made some experiments and videotaped them in order to have some material for teachers' training. This might be considered as a "learning-off-job" phase, because the group was involved in creating a common culture about IBL but their work was not focused explicitly on learning about how to facilitate teachers' profession.

In the "learning-by-job" phases, some training sessions have been implemented at various levels (primary, lower and upper secondary) with various dimensions by parts of the bunch of trainers. All training sessions were at least partly discussed with the whole group, for both, preparation and post-analysis. This phase differentiates from the one explained before in the way how teachers are now involved in professional development practices (planning, implementing and reflecting from them), therefore developing their competencies to facilitate the professional development of other teachers.

The common work helped creating a rich common culture related to maths and sciences at all educational levels. The PRIMAS national team also developed some theoretical tools from didactics and worked on the elaboration of training sessions to be used in the professional development of teachers ("learning-off-job"). This common culture was reinvested in the Geneva PRIMAS website.

3.2. The professional development of teachers

3.2.1. Case 5 - Professional development courses in Spain: an out-of-school guided intervention.

The professional development of teachers in Andalucía (Spain) followed the guided schema explained in section 2.3.1. That is, face-to-face sessions organized around some of the PRIMAS modules with some weeks in between where teachers had the opportunity to implement IBL activities with their students and to learn by doing.

Altogether, 12 PD courses were organized between 2012 and 2013 (6 sessions each, on average), lasting 4-5 months each. Modules 1 to 5 were used, most of the times with little variations (some tasks were changed and some local videos were added). On average, there was 2-4 weeks break between each face-to-face session.

From the very beginning, teachers were encouraged to use IBL tasks with their students. That was coherent with our understanding of teachers' professional development: instead of offering closed answers for unknown professional problems, we wanted them to face the challenges of implementing IBL, first. In this way, the modules are meaningful in the sense that they offer valuable guidance to deal with some of the challenges they have already faced. Besides, it was also stressed that each teacher would probably elaborate his own professional knowledge, based on the guidelines given in the PRIMAS modules but also in his experiences and professional background.

All the courses started with a common reflection about the meaning of IBL, based on the PD module 1 (student-led inquiry). That seemed to be important, as we found necessary to build up a shared understanding of the core of the whole PD programme. Since, different modules were used, depending on the course. We can inform about the two different structures widely used:

- Structure 1: following the suggestion given in section 2.3.1, after module 1, module 2 “tackling unstructured problems” was used (module 2). Then “learning concepts” (module 3) and finally modules 4 and 5 (“asking questions” and “collaborative work”).
- Structure 2: in other cases, educators find more important to focus first on collaborative work. Normally, this happened in those Teacher Centres where there was a prior work on collaborative learning. Therefore, after module 1, they moved to module 5. Next, they used “asking questions” (module 4), then module 2 (tackling unstructured problems). They left module 3 (learning concepts) for the final part of the course, because it was perceived as a major issue and they considered that it should be worked separately.

Figure 15. PD session with teachers in Alcalá de Guadaira (Seville)

Teachers attending these courses highly valued both the content of the modules and the structure of the professional development courses.

Concerning the face-to-face sessions, they valued the practical approach and the videos of the lessons as well as the clear structure and the written guidelines they received.

Concerning the period between the sessions, they appreciated the possibility of going back to school and using IBL with their students. Although many of them found it challenging, mainly on the early stage of their professional development, at the end they realized that it was a highly effective learning strategy.

Figure 16. PD session in Linares (Jaén). One teacher explaining the work with her students (including a video of the lesson).

Finally, it is worth mentioning that, as suggested by the educators, some teachers videotaped their own lessons and/or took pictures and prepared brief presentations. It was highly effective both for the teacher and the whole group. From our experience, it is important to encourage this professional learning strategy in any professional development intervention.

3.2.2. Case 6 - Professional development in England: a self-regulated intervention based on lesson study.

In England, where there is no systemic infrastructure for the professional development of teachers, PRIMAS was implemented using a number of different models. In general, those models follow a principle of providing modes of working that support self-regulated professional learning communities. These, as described in section 2.3.2, might be considered as communities of inquiry which seek to explore their own practice.

One of the models used, explored the development of Japanese lesson study in the English context. Lesson study is a well-established part of the Japanese education system, with teachers expected to be regularly involved in the detailed development of a research lesson that explores the development of teaching and learning. In England, two Higher Education institutions (one being a consortium partner) worked with 9 schools on establishing and researching the process of lesson study with the intention of being able to disseminate findings in relation to teaching using IBL as well as the lesson study process itself and considering how this might be scaled-up.

Each school initially worked with 3 teachers who form a PRIMAS cluster (one cluster comprising 5 schools and the other 4). Teachers from across each cluster attend the research lessons in each others' schools before returning to their own school, where they continue to work with colleagues there. Consequently the process might be considered having a potential impact on approaching about 100 teachers across the two clusters.

In summary, a single iteration of lesson study involves the design, teaching and critiquing of a research lesson with one school in the cluster taking the lead. One research lesson was developed in each school during each school term leading to 27 research lessons in a year.

The focus of the research lessons was the development of teaching that emphasizes the development of the students' problem-solving/inquiry skills. For example, lessons focussed on students developing justification skills, considering the social outcomes of quantitative choices, understanding the impact of mathematical and non-mathematical assumption making in modelling and so on.

The lesson planning is collaborative within school department teams with one teacher electing to teach the research lesson. The post-lesson discussion provides a reflective space where the teachers and other educationalists who attend can explore the outcomes of what they had planned. Central to understanding this is close observation of learners during the lesson with careful attention being paid to their developing understanding of the skills and mathematical concepts at issue. The interaction of teaching and learning that is put under intense scrutiny with the intention of the community coming to a shared understanding of how they might move their practice forward.

The Higher Education 'experts' provide two roles in supporting the process: they provide an organisational role facilitating the whole process in which they collaborate at each stage in addition to providing important input in the form of summarizing comments at the end of the post-lesson discussion. This 'expert' commentary is supportive and suggests ways in which the community might be moved forward in its future development. However importantly, it is the community itself that might be considered to be organic in its learning and consequently self-regulating. Through its focus on inquiry-focused teaching and learning the community is providing its own professional development, in the PRIMAS model with focus on key processes in inquiry.

As an example of an early research lesson in the development a teacher taught a lesson that had been planned to focus on students' making assumptions and justifying these when working on a modelling task. In the task the students were given a section of text from Wikipedia and asked to extract the important numerical information from this and identify what else they would need to know to solve the problem that was asked. The context was that of considering how to handle the large number of auditions of talented hopefuls would be required before the TV series that sought the singer with the special x-factor.

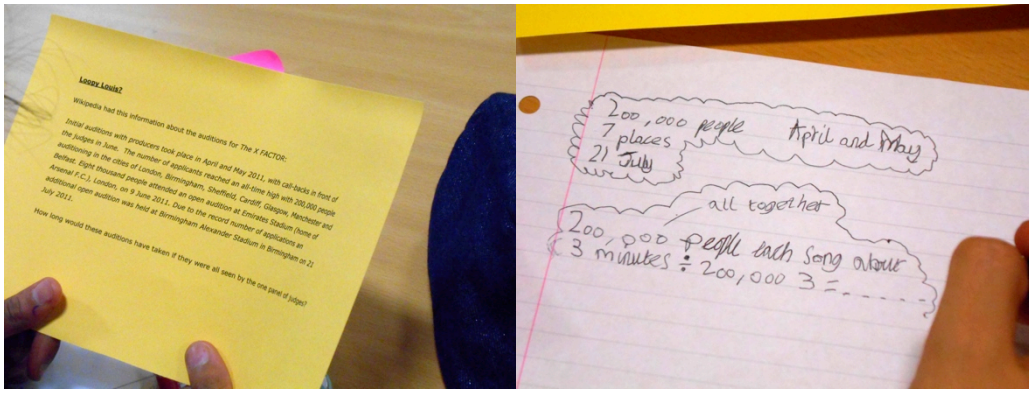

Figure 17. Pupils working on extracting information from a text and making assumptions while working on a modelling task.

The lesson proceeded with students working in pairs and being asked at key moments to explain their thoughts and methods of proceeding. In the planning before the lesson the teacher and Higher Education expert had considered what they thought might happen as students will work through the lesson. They paid particular attention to likely outcomes in representing, analysing, interpreting and evaluating, and communicating. In focusing their thinking before the lesson they considered what questions the teacher might use to facilitate learner development in these key process skills.

Figure 18. Teachers observing pupils' working during the research lesson

It was consideration of outcomes in relation to this that formed the focus of the post-lesson study with the observers drawing on their detailed observations of learners.

Figure 19. Teachers taking part in a post-lesson discussion

This single lesson took place within a period of two weeks in which each school in the cluster held their research lesson with teachers from across the cluster meeting on four occasions. PRIMAS provides resources on which the group can draw as needed including tasks for use in the classroom as well as the professional development modules. However, the greatest resource available to the group is the professional inquisitiveness of the teachers and the PRIMAS partners who have been the catalyst for the setting up of the community, and introduced and facilitated the lesson study process.

3.2.3. Case 7 – In-school professional development in The Netherlands

In the Netherlands, the professional development courses are conducted on location at school. In 2012-2013 nine schools were involved and, within each school, at least 12 teachers from mathematics and science participated.

Usually, the course consists of 4 to 5 meetings, lasting 2 ½ hours each. These include possibilities to give homework assignments (preparing and conducting alternative lessons) to the teachers. An evaluation form was sent to the teachers to facilitate the discussion of their homework assignments (see annex A).

In this case we present the results from a secondary school in the neighbourhood of Utrecht. From the schools who started in fall 2012, we will summarize some reactions teachers wrote on their evaluation form.

The first meeting

A Dutch translation of module 1 “Student-led inquiry”, with some changes, was used. Reasons for the changes were that:

- There was not enough time to do all the activities intended.
- Extra time was needed for the teachers to prepare their homework-lesson during the session.

- The Spirolaterals lesson was perceived as nice but very different from our teachers' daily practices.

The main changes were:

- Starting with *three* hands-on experiments: Spirolaterals, rolling cups and sugar lumps (science setting with cup, saucer, water, scale and thermometer).
- Cutting time on asking questions from photographs.
- Cutting time on bottle houses.
- Adding an activity – close to an activity from module 2 – with key activities from math and science books that are very structured and the questions 'why it is presented like this?' and 'can you think of alternative presentations that enhance IBL?'
- Adding a final activity where they prepare an alternative lesson with an IBL emphasis, specifically explicit attention for one or more research cycle phases.

Figure 20. Dutch teachers during the first activity

The second meeting

The Dutch translation of modules 2 & 3 was used. After the theoretical intro, we started discussing their experiences and reflecting on their experiences. Next, the plan was to hand out the final activity of PD2: "Practical advice for teaching problem solving". They could discuss in pairs what went well, what could be improved and what can be added to the list.

Goal of the activity was to discuss the fact that not all teaching should change, but that IBL is an essential ingredient of good education. Mainly module 2 (tackling unstructured problems) was used, but time was also spent in analysing and comparing lesson plans.

Finally, teachers' attention was shifted from tackling unstructured problems to the activities related to concept development in PD module 3. The homework assignment for them would be to do a lesson inspired by these activities (classifying & defining, representing & relating representations, and formulating sentences that are never, sometimes or always true).

Video

Most teachers videotaped each other's lessons. The teachers started with presentations of their experiences with alternative lessons. In order to prepare this, we handed out an evaluation sheet that they had to send in a few days before this afternoon. These sheets provided us with a lot of information (e.g. annex A; not an 'average' teacher). This part of the session took circa 1 ½ hour.

The third meeting

Experiences with PD module "Asking Questions":

- There was very limited time to work with the module (just 1 hour).
- An example of an interactive lesson was presented to the teachers. They were encouraged to think about the falling time of paper trays and the kind of variables that might be involved and how they might be related to the falling time. Teachers appreciated the role of 'thinking students' and the experience of having time to think and contribute. This activity worked well to motivate them for experimenting with the questioning techniques.
- The questioning techniques seemed more familiar for science teachers than for math teachers.

The discussion of their homework, again, took more time than expected (one hour). Videos were restricted to a compilation of one of the teachers, but still their stories are asked for reflection and comparison.

The fourth meeting

It was structured around peer feedback and self-assessment modules.

Hand-out 2 and 3 were used for this session. There was a short talk about formative assessment and the possibilities for doing this quickly and briefly (poster and whiteboards), and fragments of the English videos on this topic were shown.

There was a short explanation about peer feedback with a rubric, students work with an assessment form to provide feedback on each other's research and an assignment to have students do an open problem initially and then assess the various items of work by the students, after which they go back to improve their own work on the basis of the impressions gained. An urgent suggestion has been made to do more with this, except the assignment couldn't be set explicitly because this was the final afternoon of the course.

Schools of 2012-2013

In each school there are about 12 – 20 teachers who participate. They are teachers of Science (Chemistry, Physics, Biology) and Mathematics. Sometimes also the Technical Assistants were present (they prepare and help during the practical Science lessons).

In all groups it was mentioned that they appreciated this professional development programme since that has all the subject teachers together, which is very unusual for the

Dutch schools. They all find it very instructive to hear, see and discuss lessons of other subjects

Most groups now have finished the first two or three PD sessions. The evaluation sheets were used as a source to prepare the meetings and discussions.

From a selection of statements from the evaluation sheets of the first IBL lesson:

- About the lesson and the students
  - Because the problem was so open, the students had to be creative.
  - Usually, I decide what to do. This time the students had to think about how, what and with what they had to carry out their experiment.
  - We gave less instruction than usual. We also had now and then a whole class discussion during the lesson, what we usually not do.
  - The students showed more initiative.
  - It is nice to see with which ideas students come up with if they are not restricted by instruction.
  - Student: in this way you have to think more.
  - Students do more research instead of following my prescription.
  - The students were very motivated. They even looked for information in their book and on the Internet.
  - They really wanted to know.
  - I usually talk a lot and I ask the questions. Now the students ask questions to me an each other
  - For the practical work students usually can carry out the recipe without understanding. Now they had to think: How can I measure? What do I know about …? What is …?
  - Students are not used to work in this way.
  - Students can think by themselves.
- Teacher's reflection
  - I need to prepare some details more precisely.
  - My role was more coaching, guiding. Usually my role is presenting.
  - It costs more time. For me, it is difficult to let the students go.
  - I notice that I give student an answer too quickly. I need to pose more open questions.
  - You don't need to be afraid to give our students such open problems.
  - Preparing the lesson costs more time.
  - Students can do more than they usually show.
  - Without the course you will not so easily allow.
  - A good preparation of the lesson is a must.

Finally, just mentioning that a Dutch website (http://www.projects.science.uu.nl/primas) has been created for teachers to find suggestions for lessons, created by other teachers on behalf of the PD programme.

3.2.4. Case 8 – Professional development in Hungary: Marrying the PRIMAS IBL spirit and the requirements of a stately approved PD programme

In Hungary, in order to inspire teacher participation, we decided to "go to the market" of stately approved PD programmes. There are various possible types of stately approved programmes, and aiming at providing a financially feasible and still effective training, we chose to submit the plan of a 30 hours long PD programme. The official reviewer required many changes in the details (formative assessment points, participants' tasks), and strongly suggested to lengthen the programme, so it finally became 36 hours long.

The 'market' of PD programme is quite crowded. Anyone who submits a proposal can have the right to run PD courses (universities, research institutes, and various entrepreneurs). Although teachers are obliged to gather credit points from attending PD courses, most of them have already had more than enough, so it is not a strong motivating factor. However, it might be discouraging if a PD programme is not stately approved. The process of state approval is rather lengthy (much lengthy than is was expected…), and there are rigorous criteria that must be fulfilled with respect to – among others – the assessment criteria, the equipment needed, and detailed description of the teaching and learning methods are needed.

The programme is mainly based on the first five PRIMAS (Nottingham) modules – since at the time we submitted our proposal to the state authority, the last two modules were not yet available. A guided PD intervention was implemented, being its structure and time frame the following.

Part	Teaching and learning method	Length (hours)
The concept of IBL	lecture	6
European and nation-wide initiations for IBL	lecture	4
Student-led inquiry; observations	training	3
Unstructured problems	training	3
Learning math and science concepts through IBL	training	5.5
Questions for promoting IBL	training	3
Cooperative learning	training	3.5
Self-reflection on participants' own classroom experiences	open consultation	8

The first two parts were held by lecturers from the University of Szeged and the other parts by the multipliers.

Figure 21. Csaba Csíkos (Hungarian PRIMAS coordinator) opening the first PD session in the town Szentes

The majority of multipliers were in-service teachers who needed some time to build up self-confidence for teaching in a PD programme. Therefore, they got professional support in the training for multipliers phase. Having finished the first PD session in November 2012 and having seen the results of the feedback questionnaire, they received a high score in the important categories (commitment, teaching methods, being helpful).

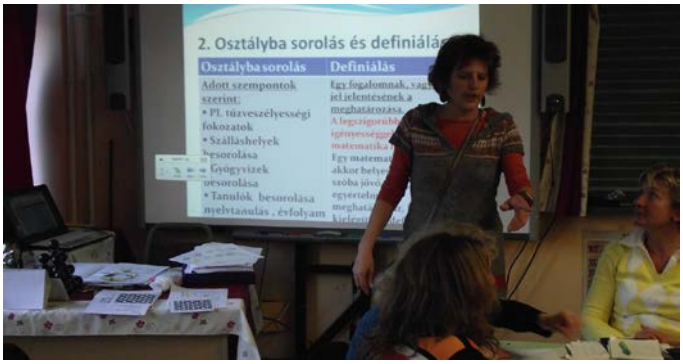

Figure 22. Terézia Balogh (PRIMAS multiplier) working on the "Learning concepts through IBL" module with teachers during a PD session.

The teachers gave reasonably high scores on a five-point Likert-scale questions about how the Hungarian multipliers worked. Even one of the teachers became so enthusiastic that she organized an open class for parents and for her colleagues. But this is another story worth telling in the guides for other kinds of dissemination actions (visit PRIMAS website).

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Annex A: Evaluation form experimental lesson in course "Inquiry-based learning"

<table>
<tr><td>Name</td><td colspan="3">Corine van den Boer</td></tr>
<tr><td>Subject</td><td>Mathematics</td><td>Class</td><td>2 vwo (grade 8)</td></tr>
<tr><td rowspan="3">Which activity was used (short description)</td><td>Book, paragraph</td><td colspan="2">Getal en Ruimte; H3, paragraph 2</td></tr>
<tr><td colspan="2">Replacement for book or extra material?</td><td>In addition to regular material</td></tr>
<tr><td colspan="3">Based on some examples, I let the students formulate for themselves what was so strange about the strange products on the smart board.

The students did know that they can write out something like (3x +5)^2 as (3x+5)(3x+5), but they don't yet know what a strange product is. Then I went on to let them formulate the general rule themselves.

I explained this in three tasks that they were given via the smart board.</td></tr>
<tr><td>How did you adapt the activity, or what did you include specifically in your activity to stimulate inquiry-based learning?</td><td colspan="3">The students had to find the regularity themselves. They were given increasingly less guidance in subsequent assignments.

They also had to work in groups, where I could select someone who then had to be able to describe the whole group's findings.

After every sheet (on the smart board) the students had an opportunity to discover the regularity in groups. We discussed it with the whole class, followed by the next problem. Because the assignment was shown on the smartboard, the students were all working on the same problem (if you're working on paper, there are always a few students who go looking ahead because they think they've more or less solved the problem, or to see what else is coming).</td></tr>
<tr><td>Why do you think that your approach/adaptation will stimulate inquiry-based learning?</td><td colspan="3">Students do not get a certain approach presented ready-made but they have to discover it themselves. It turns out that they are capable of doing so. This gives students the confidence that they can in fact solve a situation where they don't know immediately how to handle it.

Students become more and more acquainted with the idea that it's the process that is important and not just the product (in this case, knowing the rule for the strange product). They also learn</td></tr>
</table>

	to look at a problem more critically, not to conclude too fast that if it's like that in one situation, it's probably true always.
Experiences during the lesson: what was student behaviour like and what was the yield (different than normal)	The students were very involved. They listened well to each other and were eager to discover the regularity. The aim was that the students gained ownership over the result: they understood how strange products were structured. They themselves introduced the use of a and b in the general description. In other years it is confusing for a group of students when they subsequently have to reduce something like (3a + 6)^2. The 'a' from the problem is a different 'a' than the one in the general rule about strange products (signifying values <> signifying formulas). In the final discussion, a group had come up with (a-a)(a+b) as a strange product. That was a surprise, and it has been named the strange product of Class M2D. The other week, the students will sit their final test on this topic, so today we went through the chapter again, and of course the strange products came up as well, all three appearing on the board. However, the students called out enthusiastically "*and* the strange product of M2D!" They could even still tell what it was.
Was the result of the activity what you expected? What did you learn from it?	It took more time than planned (of course) but afterwards they were all able to work with the strange products. I didn't discuss the theory from the book at all, it was unnecessary. There are still students who rather would write it out, that is the case every year, but my impression is that all students understand how it works, and that is new to me. There is always a group where you toil to explain, and sometimes even let it go with a sigh and, "If you really don't see how it works, just try to remember really well ".
Will you do this activity or a similar one more often?	I already had the students research even and odd powers of a positive and a negative number by themselves. At the time, we looked at formulating the rule in great detail. These positive experiences make that mathematics starts to belong to the students more and. That is a stimulus for me to give them this kind of assignment more often.
What else would you like to mention?	I already try to ask open questions often, and to make the students think. The course raises my awareness even more, and I will use this more for larger assignments.