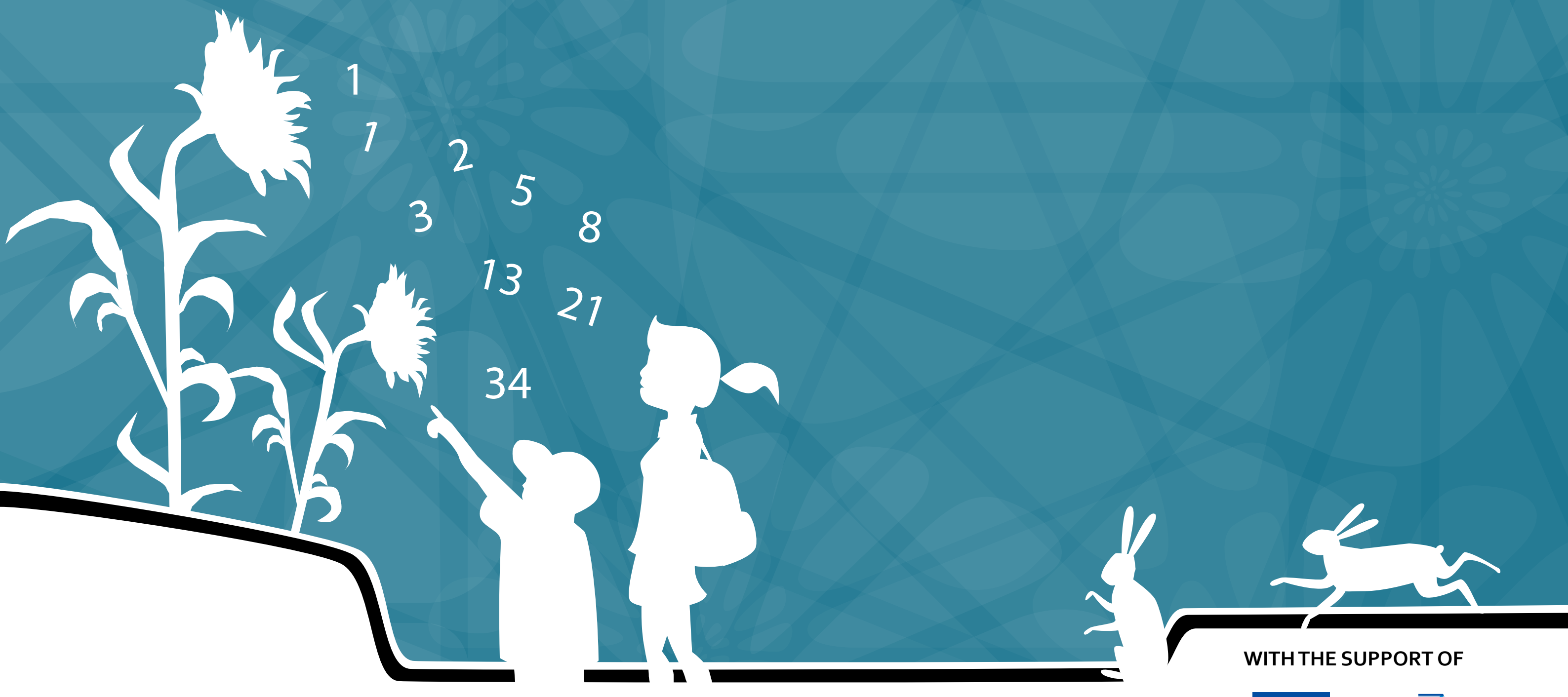
The Fibonacci Project

DISSEMINATING INQUIRY-BASED SCIENCE AND MATHEMATICS EDUCATION IN EUROPE

Companion Resources For Implementing Inquiry in Science Education

Tools for Enhancing Inquiry in Science Education



WITH THE SUPPORT OF
EUROPEAN COMMISSION
SEVENTH FRAMEWORK PROGRAMME

Resources for Implementing Inquiry in Science and Mathematics at School

The Fibonacci Project (2010-2013) aimed at a large dissemination of inquiry-based science education and inquiry-based mathematics education throughout the European Union. The project partners created and trialled a common approach to inquiry-based teaching and learning in science and mathematics and a dissemination process involving 12 Reference Centres and 24 Twin Centres throughout Europe which took account of local contexts.

This booklet is part of the *Resources for Implementing Inquiry in Science and in Mathematics at School*. These Resources include two sets of complementary booklets developed during the Fibonacci Project:

1) Background Resources

The *Background Resources* were written by the members of the Fibonacci Scientific Committee. They define the general principles of inquiry-based science education and inquiry-based mathematics education and of their implementation. They include the following booklets:

- 1.1 Learning through Inquiry
- 1.2 Inquiry in Science Education
- 1.3 Inquiry in Mathematics Education

2) Companion Resources

The *Companion Resources* provide practical information, instructional ideas and activities, and assessment tools for the effective implementation of an inquiry-based approach in science and mathematics at school. They are based on the three-year experiences of five groups of Fibonacci partners who focused on different aspects of implementation. The *Companion Resources* summarise the lessons learned in the process and, where relevant, provide a number of recommendations for the different actors concerned with science and mathematics education (teachers, teacher educators, school directives, deciders, policy makers...). They include the following booklets:

- 2.1 Tools for Enhancing Inquiry in Science Education
- 2.2 Implementing Inquiry in Mathematics Education
- 2.3 Setting up, Developing and Expanding a Centre for Science and/or Mathematics Education
- 2.4 Integrating Science Inquiry across the Curriculum
- 2.5 Implementing Inquiry beyond the School

Reference may be made within this booklet to the other *Resource* booklets. All the booklets are available, free of charge, on the Fibonacci website, within the *Resources* section.

Editorial coordinator : Susana Borda Carulla

Fibonacci Scientific Committee : Michèle Artigue, Peter Baptist, Justin Dillon, David Jasmin, Wynne Harlen, Pierre Léna

WWW.FIBONACCI-PROJECT.EU

Fibonacci Project, December 2012

This project has received funding from the European Union's Seventh Framework Programme

Tools for Enhancing Inquiry in Science Education

Editorial coordinator : Susana BORDA CARULLA (Fondation La main à la pâte, France)

Scientific advisor : Wynne HARLEN (Fibonacci Scientific Committee)

Contributors:
Gerd BERGMAN (Royal Swedish Academy of Sciences / NTA Development, Sweden)
Susana BORDA CARULLA (Fondation La main à la pâte, France)
Marida ERGAZAKI (University of Patras, Greece)
Wynne HARLEN (Fibonacci Scientific Committee)
Katarina KOTUL'ÁKOVÁ (University of Trnava, Slovakia)
Anna PASCUCCI (Italian Association of National Science Teachers, ANISN, Italy)
Jan SCHOULTZ (Linköping University, Sweden)
Clémentine TRANSETTI (Graduate School of Engineering of Saint-Étienne, France)
Kristina ZOLDOZOVA (University of Trnava, Slovakia)

Table of contents

Introduction to the *Tools for Enhancing Inquiry in Science Education*

Chapter coordination: Susana Borda Carulla

What are they?

The *Tools for Enhancing Inquiry in Science Education* were designed to support the effective implementation of an inquiry-based approach to science teaching. The tools result from three years of collaborative work among science education researchers, science teacher trainers, and science teachers with different levels of experience in implementing inquiry-based science education. The production of these tools involved partners from six different European countries: France, Greece, Italy, Slovakia, Sweden, and the United Kingdom. The tools were trialled on four different occasions in classrooms and with teachers from the first five countries mentioned. These trials have shown that the tools are flexible enough to be adapted for use in various cultural and social contexts, and within various educational systems.

The *Tools for Enhancing Inquiry in Science Education* comprise a *Diagnostic Tool for CPD Providers* and a *Self-Reflection Tool for Teachers*. They were designed to provide teachers and teacher trainers with the means to enhance inquiry in the science classroom, mainly through observation of and reflection on classroom practises. They help teachers and teacher trainers to a better understanding of what is meant by teaching and learning through scientific inquiry, by providing trainers with the means of diagnosing strengths and weaknesses in science teaching practises, and teachers with the means to reflect on their own teaching.

The *Diagnostic Tool for CPD Providers* and the *Self-Reflection Tool for Teachers* each consist of three equally important parts: a set of instructions for use and two forms, one for use in primary and middle schools, and another for use in kindergarten. The forms include the items or questions that compose the tool, the criteria for evaluating each item, and the necessary space to make the evaluation and record qualitative data. The instructions for use are included within the text of the booklet. The forms for primary and middle school can be found in **ANNEX 1** and **ANNEX 2,** and the forms for kindergarten can be found in **ANNEX 3** and **ANNEX 4**.

The *Diagnostic Tool for CPD Providers* and the *Self-Reflection Tool for Teachers* were designed to be used in a complementary manner. Thus, for every item in the *Diagnostic Tool for CPD Providers* form, there is a parallel item designated by the same number in the *Self-Reflection Tool for Teachers* form.

> The *Tools for Enhancing Inquiry in Science Education* comprise:
> - The *Diagnostic Tool for CPD Providers*
> - The *Self-Reflection Tool for Teachers*.
>
> Each tool includes instructions for use and a form. The tools are complementary: on each form, each item has a corresponding item with the same number in the other form.

How do they enhance inquiry?

Helping to deepen the understanding of inquiry

Learning through scientific inquiry refers to the process of building understanding by developing and using scientific investigation skills[1]. 'Understanding' here relates to the development of powerful (or 'big') scientific

1 For a full discussion of the meaning of inquiry in science education, please refer to the Fibonacci Background booklet Inquiry in Science Education, available at www.fibonacci-project.eu, in the Resources section.

ideas which enable learners to make sense of the events and phenomena in the surrounding world[2]. However, a broad definition of inquiry in science education is not sufficient to guide practise. The role of broad definitions is to convey what is valued and intended overall, but in order for this to be achieved it is necessary to consider in much greater detail the actions and interactions of teachers and pupils.

The development of understanding depends on the way in which skills involved in collecting, analysing and interpreting evidence are used. Students, particularly young children, do not instinctively use these skills and, when they do, they may not use them in the way that scientists do. When skills are not used in a scientific manner, the naïve and non-scientific ideas that children may hold will not be challenged. Hence the importance of teachers encouraging their pupils to use and develop these skills.

Consider first what experiences pupils need to have in order to progressively develop their skills and understanding in science. The experience of various projects on inquiry-based science education[3] and using what research tells us about how pupils learn best[4] leads to the formulation of the items included in *Section B* of the forms of both *Tools for Enhancing Inquiry*. These pupil activities have their counterpart in teacher practises. Inquiry-based teaching practise is exemplified in *Section A* of the forms of both tools.

Supporting formative assessment of teaching practises

Formative assessment, or assessment for learning, has the same role in relation to the learning of teachers as it does to the learning of pupils. In the context of the teachers developing the skills of inquiry teaching, it helps to ensure that there is progression in learning and regulates the teaching and learning process to ensure learning with understanding, by providing feedback to both the trainer and the teacher.

The *Diagnostic Tool for CPD Providers* was designed to give teacher trainers the means to identify teachers' training needs and to give them feedback on the impact of their training in the classroom practise. Trainers can thus identify the aspects of inquiry-based teaching with which teachers are having difficulty and decide what, if any, adjustments need to be made to the training provided. The tool is also useful in identifying training needs when designing a training programme.

Formative assessment of teaching practises is useful not only to trainers, but also to teachers. It involves teachers in assessing their own achievement and in deciding the steps they need to take to improve it or move on. Using the *Self-Reflection Tool for Teachers* helps teachers reflect on the goals of inquiry-based science teaching and focuses their attention on the key aspects of practise that enable pupils to learn through inquiry. It alerts teachers to aspects that may be missing from pupils' experience and possible reasons for this, gives them information about what needs to be improved in their practise, and provides a means for them to monitor the changes they are trying to implement in their teaching.

Since the tools were designed to be used in a complementary manner, once teacher trainers have identified the training needs of teachers using the *Diagnostic Tool for CPD Providers*, they may find it useful to ask teachers to use the *Self-Reflection Tool for Teachers* to work on the particular aspects of inquiry-based teaching with which they are having difficulty.

2 See Harlen, W. (2010). *Principles and Big ideas of Science Education*. Hatfield, UK: ASE.

3 The projects in question are the following: interAcademy Panel on International Issues. See especially IAP (2006). *Report of the Working Group on International Collaboration in the Evaluation of Inquiry-based Science Education (IBSE) programs*, Santiago, Chile: University of Chile, Faculty of Medicine.

The French project *La main à la pâte*: www.fondation-lamap.org.

The European Pollen Project (precursor to the Fibonacci Project): www.pollen-europa.net.

4 See Duschl, R. A., Schweingruber H.A. and Shouse, A.W. (eds.) (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8.* Washington DC: The National Academies Press, and Bransford, J., Brown, A. and Cocking, R. (eds.) (2000). *How People Learn*. Washington, D.C.: National Academy Press.

Cautions about using the *Tools for Enhancing Inquiry in Science Education*

Two crucial points should be kept in mind before using the *Tools for Enhancing Inquiry in Science Education*:

1) Many educational actors are eager for tools that help them evaluate teachers' progress in their teaching career. It is important to keep in mind that these tools were NOT designed for this purpose and it would be erroneous and misleading to use them to score teachers on their teaching.

2) Not all learning in science involves inquiry: when understanding is the aim, then inquiry is the appropriate approach, but conventions, names, etc., are best taught directly. Thus, the *Tools for Enhancing Inquiry in Science Education* do not convey all positive features of science teaching practise, only those that are specific to an inquiry-based pedagogy.

The *Tools for Enhancing Inquiry in Science Education*:

- were not designed to score teachers on their teaching;
- do not convey all positive features of science teaching practise, only those specific to an inquiry-based pedagogy.

1. The *Diagnostic Tool for CPD Providers*

Chapter coordination: Susana Borda Carulla

The *Diagnostic Tool for CPD Providers* helps CPD providers to diagnose teachers' CPD requirements and gives them feedback on training priorities. Data is recovered mainly through observation and analysis of classroom practises.

1.1 What is it?

The *Diagnostic Tool for CPD Providers* helps to diagnose Continuing Professional Development (CPD) requirements and give feedback to the providers concerning training priorities. Its purpose is to identify across a range of classroom conditions, the aspects of inquiry-based teaching and learning that are being well implemented and those where attention is needed. It comprises a set of instructions on planning and coordinating an evaluation, and a form (**ANNEX 1**). The form includes a list of indicators for judging the implementation of inquiry-based science education by observing and analysing classroom practises in primary and middle school and in kindergarten, respectively.

The *Diagnostic Tool for CPD Providers* form has four sections:

- **Interview with the teacher**: Collects information about: I) The observer; II) The session observed; III) The class observed; IV) The teacher; and V) The topic and objectives of the session.
- **Section A: Teacher-pupil interactions**: Reports observations about: 1) Building on pupils' ideas; 2) Supporting pupils' own investigations; and 3) Guiding analysis and conclusions.
- **Section B: Pupil activities**: Reports observations about pupils: 4) Carrying out investigations; and 5) Working with others.
- **Section C: Pupils' records**: Reports information taken from looking at: 6) Any records pupils make of their work; 7) Their written records.

Where teacher actions have parallels in pupils' actions, repetition of the item was avoided, except when retaining related items in both aids data interpretation. For instance, encouraging pupils to express their own ideas appears in section A, without parallel items in section B. On the other hand, asking pupils to think of reasons or explanations for their findings is included in section A and also has a parallel item in section B because there may be many reasons (other than the teacher's encouragement) for pupils not making sense of what they find. Thus, it is important to look at the tool as a whole in considering whether it covers all important aspects of inquiry-based teaching and learning.

In sections A, B and C there are 'Explanations and Examples' beside each item to help clarify the meaning of the item. For items in these sections, evaluation is recorded as 'yes', 'no' or 'not applicable' (NA).

ANNEX 1 presents the *Diagnostic Tool for CPD Providers* form. Carefully read the instructions on planning and coordinating an evaluation before using the form.

1.2 Instructions for use: planning and coordinating an evaluation

1.2.1 Deciding on the objective of the evaluation

The *Diagnostic Tool for CPD Providers* may be used for several purposes. For example:

- When designing a CPD programme, it may be useful to diagnose the state of science teaching practises of a particular group of teachers, in order to obtain information on the main difficulties they are encountering in the classroom.
- Within a CPD programme which is already in place, it may be useful to obtain information on the impact of a particular set of CPD actions, in order to eventually reconfigure CPD efforts if need be; it may also be interesting to see whether classroom practises of a particular group of teachers are improving as they acquire inquiry-based teaching experience.

1.2.2 A few pre-requisites for inquiry

The *Diagnostic Tool for CPD Providers* was designed to focus on specific interactions between teacher and pupils and among pupils that indicate inquiry-based science education. This means that many aspects of good practise, which are not specifically indicative of inquiry but which are nevertheless indispensable for inquiry to take place, are not included in the tool. CPD providers should check whether the following aspects of practise are in place before engaging in a diagnosis of inquiry-based teaching and learning with this tool. The absence of these features may inhibit inquiry-related activities.

- The materials and equipment provided are appropriate for the activities and age of the pupils
- Pupils have access to secondary sources of information such as books, the Internet, posters
- Pupils are organised so that they can work in small groups
- The session is organised so that sufficient time is given to discussing pupils' ideas, clarifying the question being investigated, collecting data, discussing what has been done and found out
- Pupils have notebooks or folders, as appropriate to their age, for keeping their records
- Pupils are taught techniques for using equipment, including measuring instruments, safely and effectively
- Pupils are helped to use appropriate scientific terms and representations
- Tolerance and mutual respect in class and discussions are encouraged

Many aspects of good practise, which are not specifically indicative of inquiry but which are nevertheless indispensable for inquiry to take place, are not included in the tool. Make sure that the above pre-requisites are met before you use the tool.

1.2.3 Selecting and training the observers

It is important that observers who will use this tool:

- are familiarised with fundamentals and practises of inquiry-based science teaching and learning;
- have either science teaching experience, or experience in observing science lessons;
- are accustomed to interacting with teachers.

It is nevertheless important to train observers before engaging them in class observations. There are two reasons for this:

1. Even though the items included in the tool have been tested and adjusted for greater reliability, and examples of real classroom practises have been included for each item, some margin of interpretation

exists, especially given the large number of contextual differences in the implementation of inquiry-based science education in different countries and/or CPD programmes. Thus, before undertaking an evaluation, it is very important that within each CPD programme, the CPD providers and the group of observers agree on the way in which they will interpret each item.

2. Discussing the meaning of each item can be a very formative process for all actors within a CPD programme, for it allows the identification of possible differences in the interpretation of programme objectives and means of action.

Observers can be trained by introducing them to the observation tool and then having them evaluate a class session observed on a video. Ask them to compare their results, discuss any differences in their evaluations, and determine as a team how each classroom practise will be interpreted and recorded and why.

> Train the observers before engaging them in class observations. Make sure that the CPD providers and the group of observers agree on the way in which they will interpret each item.

1.2.4 Planning the class visits

> At what time of the school year should class visits be planned?

It all depends on the objective of the evaluation. For example:

- If the objective is to diagnose the state of science teaching practises of a particular group of teachers in order to have input for designing a CPD programme, then observations can be made at any time during the school year.
- If the objective is to obtain information on the impact of a particular set of CPD actions, then a pre-CPD/post-CPD evaluation design would be advisable, with two sets of observations, one planned immediately before the implementation of the CPD actions, another immediately after.
- If the objective is to see whether a particular group of teachers are improving as they acquire inquiry-based teaching experience, a pre/post evaluation design would also be advisable, with observations planned at the beginning then at the end of the school year.

> How many consecutive science sessions should be observed?

The form in **ANNEX 1** was designed to observe one science session. A session is a time period (usually 45 to 60 minutes) during which one or many science educational activities may take place. The more consecutive sessions taught by a particular teacher are observed, the more chances providers will have of recovering useful information on all aspects of the implementation of inquiry-based science education and avoiding frequent use of the option 'not applicable'. Keeping this in mind:

- It is ideal to observe a full sequence. A sequence is a set of consecutive sessions aimed at one common learning objective, covering a full inquiry cycle.
- Since observing a full sequence is often not possible, we recommend that at least two consecutive science sessions be observed for each teacher.

Remember to use a separate form for each session.

> The form in **ANNEX 1** is designed to observe one science session. Ideally, observe a full sequence for each teacher. If this is not possible, then observe at least two consecutive science sessions for each teacher.

1.2.5 Gathering the data

> Preparing the visit

Before visiting a class, it is important to explain the purpose of the visit to the teacher: remind them that this tool is not meant to 'score' them on their teaching (no summative evaluation will result from these observations) and will have no repercussions whatsoever in terms of their teaching career. The tool is meant to give formative feedback to CPD providers.

It is also important to plan at least 15 minutes for an interview with the teacher, either before or after the science lesson, and another 15 minutes to look over students' written records.

> Make sure the teacher understands the objective of your visit: give formative feedback to CPD providers, not evaluate their teaching. Plan a 15-minute interview with the teacher and some time to look over students' written records.

> During the visit

- **Before or after the science lesson:** items in the section 'Interview with the teacher' of the form in **ANNEX 1** are to be completed through an interview with the teacher. Items in section C ('Pupils' written records') are to be completed by analysing several pupils' written records (ideally, at least one record from each group of pupils), which can be done either before, after, or during the lesson.
- **During the science lesson**: in order to fill in sections A and B of the form, we recommend that observers take notes on a separate sheet of paper, to remind them of specific events, and then record their evaluation and their comments on the form only after the lesson is finished. Observers may choose to organise their notes in two separate sections corresponding to those of the forms: 'Teacher-pupil interactions' and 'Pupils' activities' (interactions among pupils or activities in which the teacher is not involved).

> Make sure you know how and when to recover the information to fill in each section of the form in **ANNEX 1**. Fill in the form only after the lesson is over. During the lesson, take notes on a separate sheet of paper.

> After the visit

It is important to record on the form in **ANNEX 1** quickly after the class is over, so that the details will not be forgotten. For items in Sections A, B, and C of the form, evaluation is recorded as 'yes', 'no' or 'not applicable' (NA):

- **YES** implies that the **practise occurred** and that it was **relevant** in the context of the observation.
- **NO** implies that the **practise did not occur** at all or **occurred only rarely**, but that it **was relevant** in the context of the observation.
- **NA** implies that the **practise is not relevant** in the context of the session observed. There may be many contextual reasons for recording NA. For example:
  - The item is not relevant for the particular session being observed. For instance, items 4e – 4i, which concern the execution of an experimental design, are not relevant for a session in which pupils designed an experimental plan and stated hypotheses but did not actually carry out the experiment.
  - The item is not relevant for the type of inquiry activity being observed. For instance, items 2e and 4d, which concern fair testing, may not be relevant in an inquiry activity where only observation is involved.

Observers use the column 'Complementary information' to provide qualitative evidence to support their decision. It is very important that observers provide supporting evidence for all items marked as 'No' and as 'NA': this information will help CPD providers to make a clearer diagnosis and to adapt their training strategies to the problems that teachers are encountering.

Carefully study the criteria for evaluating 'yes', 'no', or 'NA'. Fill in the form in **ANNEX 1** quickly after the class is over. Provide supporting evidence for all items marked as 'No' and 'NA' by filling in the column 'Complementary Information'.

1.2.6 Analysing the data

The way to go about data analysis depends mainly on the objective of the evaluation. Nevertheless, the following are good starting points in all cases.

> *Organising the data: passing from 'sessions' to 'teachers'*

Box 1 shows an example of an efficient way to organise the data recovered on an Excel document.

Box 1

Example of an efficient way to organise the data recovered with* the Diagnostic Tool for CPD Providers *on an Excel document.

	Items																	
	1a			1b			1c			2a			2b			2c		
	yes	no	NA	yes	no	NA	yes	no	NA	yes	no	NA	yes	no	NA	yes	no	NA
Teacher 1	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Session 1	1	0	0	0	1	0	0	0	1	0	0	1	0	0	1	1	0	0
Session 2	1	0	0	0	1	0	0	0	1	0	1	0	1	0	0	0	1	0
Teacher 2	**1**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**1**	**0**
Session 1	1	0	0	0	1	0	0	0	1	1	0	0	1	0	0	0	0	1
Session 2	1	0	0	0	1	0	0	0	1	0	1	0	0	0	1	0	0	1
Session 3	1	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	1	0

If the tool has been used properly, then there should be at least two different records for every teacher observed, corresponding to the two consecutive class sessions observed (as for Teacher 1 in **Box 1**). There may also be more than two records for every teacher (as for Teacher 2 in **Box 1**). The first step is to create a record for each teacher by combining the records for each session. This is not a straightforward set of decisions about each item based on whether there are more 'yeses' or 'nos'. Instead it is important also to look at whether 'NA' has been reported. If there is no 'NA' recorded, then a 'No' means that a teacher missed an opportunity and may need some help to avoid this in the future. Thus the criteria for deciding the overall record are the following:

- If, among the sessions observed, there is at least one 'No' for this item, then the record for the teacher in this particular item will be 'No' (as for items 1b, 2a and 2c in **Box 1**).
- The only occasion in which an item is 'NA' for a particular teacher is when this item was 'NA' for all sessions observed for this teacher (as for item 1c in **Box 1**).
- The two previous criteria imply that:
  - the only circumstances in which an item is 'Yes' for a particular teacher is when the item was marked 'Yes' in all the sessions observed (as for item 1a in **Box 1**), or when the item was marked 'Yes' in some sessions and 'NA' in other sessions (as for item 2b in **Box 1**).
  - the only circumstances in which an item is 'NA' for a particular teacher, is when the item was marked 'NA' for all the sessions observed for this teacher (as for item 1c in **Box 1**).

The more consecutive sessions are observed for each teacher, the more complete and thus reliable the data will be. If a full sequence has been observed for each particular teacher, there should be few or no 'Not Applicable' items once the data is organised.

When deciding on an overall record for a teacher on a particular item, do not base your decision on the frequency of 'Yes', 'No', or 'NA': take a close look at the criteria above for taking your decision.

> *Identifying high 'No' and 'NA' frequencies and searching for explanations*

- Within the whole group of teachers taking part, calculate the frequencies of 'Yes', 'No', and 'NA' answers for each item.
- Identify the items for which there are high 'No' frequencies. 'No' answers imply that the practise did not occur at all or occurred only rarely, but that it was relevant in the context of the observation. Thus, a high frequency in 'No' answers for a given item implies that the corresponding practise is often absent from the classroom and could denote a particular need for attention within a CPD training programme.
- Identify the items for which there are high 'NA' frequencies. 'NA' implies that the practise is not relevant in the context of the observation. A high 'NA' frequency for a given item may thus imply that teachers are not creating the necessary learning situations for that particular aspect of inquiry to be addressed. In which case it may be relevant to support them in modifying their teaching plans so that they include those learning situations.
- If the tools were properly filled in by the observers, the qualitative data corresponding to 'No' and 'NA' items should give the CPD provider insights on the specific problems the teachers encountered. Within this tool, qualitative data is the key to an appropriate interpretation of quantitative data.

> *Grouping items for analysis*

In certain contexts it may be useful to regroup items that are indicators of particular dimensions of inquiry-based science education that a CPD programme may have focused on or is interested in assessing. For instance, the focus may include the type and use of questions by teacher and pupils, in which case items 1a, 2a and 2b will be of particular interest. The way in which items will be grouped for analysis depends entirely on the CPD actions which have been undertaken and/or on the priorities of the CPD programme.

> *Comparing teaching and learning practises*

for items in Section A ('Teacher-student interactions') with high 'No' frequencies, it may be interesting to ask whether the corresponding item or items in Section B ('Interactions among pupils') also have high 'No' frequencies. If this is not the case, then it may be that the teacher has previously trained the pupils in this particular aspect of inquiry, and that they are now autonomous and do not need the teacher's guidance. Thus, comparing items in Section A and items in Section B of the form can allow CPD providers to identify forms of open inquiry (as opposed to guided inquiry) that may successfully be taking place in the classroom.

Within this tool, qualitative data is the key to interpreting quantitative data. Always take the context into account before jumping to conclusions on the basis of patterns identified in the quantitative data. It is crucial to identify the reasons why these patterns occur.

2. The *Self-Reflection Tool for Teachers*

Chapter coordination: Wynne Harlen

The *Self-Reflection Tool for Teachers* provides teachers with the means to identify the aspects of inquiry-based teaching that they need to work on. The form provides a series of questions that the teacher can ask him/herself about a particular science lesson.

2.1 What is it?

The *Self-Reflection Tool for Teachers* provides a list of indicators for judging the implementation of inquiry-based teaching through self-analysis of classroom practises. The indicators, or criteria, are expressed as questions which teachers can ask themselves about a sequence of science activities which were intended to enable pupils to learn through inquiry. An important reason for undertaking self-evaluation is that it raises awareness of relevant aspects of pupils' work that may otherwise go unnoticed and not given the attention they deserve. The time that a teacher has to interact with each pupil in the class is normally less than thirty seconds in a one-hour lesson, so it is essential that best use is made of this time, to notice and respond to what is significant in pupils' actions and talk relevant to their learning in science, and particularly their learning through inquiry.

The *Self-Reflection Tool for Teachers* comprises a set of instruction for preparing for self-reflection, and a form, which can be found in **ANNEX 2**.

ANNEX 2 presents the *Self-Reflection Tool for Teachers* form. Carefully read the instructions on preparing for self-reflection before using the form.

2.2 Instructions for use: preparing for self-reflection

2.2.1 A few pre-requisites for inquiry

There are many features of classroom practise that indicate good practise in teaching science which are not specifically related to learning through inquiry. The tool would be very long if all of these were included, weakening its focus on inquiry. These important general aspects of good practise are listed here and teachers are urged to check that these are in place before turning to the features that indicate inquiry-based practise:

- providing materials and equipment that are appropriate for the activities and age of the pupils;
- providing access to secondary sources of information such as books, computers, posters;
- arranging the class so that pupils can work in well organised groups;
- organising the session so that sufficient time is given to discussing pupils' ideas, clarifying the question being investigated, collecting data, discussing what has been done and found out;
- teaching techniques for using equipment, including measuring instruments, safely and effectively;
- providing notebooks or folders, as appropriate to the age of the pupils, for pupils to keep their records;
- helping pupils to express themselves in appropriate scientific terms and representations;
- encouraging tolerance and mutual respect in class and discussions;
- displaying pupils' work in the classroom.

Teachers should ensure that these aspects of practise are in place as a basis for inquiry-based learning**,** since their absence may inhibit inquiry-related activities.

Check that these pre-requisites are in place before using the form in **ANNEX 2**.

2.2.2 Becoming familiar with the criteria

Before using this tool, it is important to study it and become familiar with the criteria. This will enable the teacher to focus on specific aspects of pupils' behaviour that are significant in inquiry-based learning, rather than on irrelevancies.

The form in **ANNEX 2** has three sections:

- **Section A: The teacher's role**: Includes questions on: 1) Building on pupils' ideas; 2) Supporting pupils' own investigations; and 3) Guiding analysis and conclusions.
- **Section B: Pupil activities:** Includes questions on: 4) Carrying out investigations; and 5) Working with others.
- **Section C: Pupils' records**: Includes questions on: 6) Any records pupils make of their work; 7) Pupils' written records.

Beside each question there are examples of what the questions can mean in terms of good inquiry-based teaching practise. Enough time should be spent reading the items and the examples carefully and discussing them with peers. Teachers may find it helpful to discuss the questions with peers and exchange other examples of good practise, different from those given.

Spend enough time reading the questions and the examples of the form in **ANNEX 2** and discussing them with peers before using the form.

2.2.3 Gathering evidence on classroom practises

It can be very difficult to work on improving all aspects at the same time through self-evaluation, particularly for teachers new to inquiry-based work. Thus, after becoming familiar with the full set of questions, some teachers may wish to select a certain number of questions which refer to aspects of their practise that need the most attention and are relevant to pupils' work and progress. During a lesson, or sequence of lessons during which inquiry-based activity is planned, the teacher makes observations and gathers evidence during normal work with these few questions in mind.

Responses are recorded on the form as 'Yes', 'No' or 'Not Applicable' (NA):

- **YES** implies that the **practise occurred** and that it was **relevant** in the context of the observation.
- **NO** implies that the **practise did not occur** at all or **occurred only rarely**, but that it **was relevant** in the context of the observation.
- **NA** implies that the **practise is not relevant** in the context of the session observed. There may be many contextual reasons for recording 'NA'. For example:
    - The item is not relevant for the particular session being analysed. For instance, items 4e – 4i, which concern the execution of an experimental design, are not relevant for a session in which pupils designed an experimental plan and stated hypotheses but did not actually carry out the experiment.
    - The item is not relevant for the type of inquiry activity being analysed. For instance, items 2e and 4d, which concern fair testing, may not be relevant in an inquiry activity where only observation is involved.

It is important to note reasons for the responses as much as possible since these are likely to indicate some action that could be taken. It may be helpful to make brief notes as a reminder of particular events.

There are various ways of gathering information. Some teachers may wish to make a point of talking with groups of pupils, or listening to their discussions, to find out about their ideas and what they think about their activities. Others prefer to make sound recordings of group discussions or pupils' reports to the whole class. After the lesson or sequence of lessons, teachers then review pupils' written records, their own notes and the recalled or recorded events and use this information to reflect on the lesson and answer the questions in the form.

This procedure is not intended to be carried out frequently. It is an occasional activity to help teachers review their practise, particularly when new aspects are being attempted. Thorough analysis of a record made occasionally is more important than more frequent records considered only superficially. However, the practise of self-reflection, which is developed by using this tool, is a means to deepening understanding of inquiry-based teaching and how it is implemented.

Don't work on all the questions at the same time: select a few questions relevant to the aspects of your teaching that you think need most attention and to the type of work you are doing with your pupils.

2.2.4 Reflecting, analysing and taking action

The title of this tool indicates its main function, which is to stimulate reflection on the teaching and learning that has taken place in the session(s) considered. Although no formal assessment of learning may have taken place, it is important to reflect on the opportunities pupils had to develop their initial ideas and move towards more scientific ideas about the objects of phenomena they were investigating. Was there evidence in what pupils said or recorded of them testing ideas and constructing others that better explained what they found? Were they attempting to apply what they found to other similar situations and so develop 'bigger' ideas from 'small' ones? Did they have the opportunity to use skills employed by scientists such as raising questions, making predictions, collecting data, reasoning, drawing conclusions and discussing results? Then, in reflecting on the teaching, were the pupils encouraged to do these things? Looking at the details of records of pupils' activities and the teacher's role will aid this reflection.

Answering 'Yes' to as many questions as possible indicates involvement in inquiry. This will not happen for every sequence of activities, as some questions may not be relevant. However, when a question is considered to be 'Not Applicable', it is important to ask 'why not?' There may be good reasons perhaps related to the subject matter. Or it may be that opportunities for using and developing inquiry skills were missed, perhaps because the subject was taught as it has always been done without thinking about alternatives which would have involved pupils more actively in investigation.

Where teacher actions have parallels in pupils' actions, repetition of the item was avoided, except when leaving both aids data interpretation. For instance, encouraging pupils to express their own ideas appears in Section A of the form, without parallel items in Section B. On the other hand, there are several aspects of practise which appear in pairs of questions relating to the teacher's role and the pupils' activities, for example:

- Teacher's role, question 3d 'Did you ask pupils to think of reasons or explanations for what they found?'
- Pupils' activities, question 4i 'Did pupils propose explanations for their results?'

If the answer to question 4i is 'No' then it is important to look at the answer to question 3d. This will indicate whether the action to be taken is for the teacher to include this in future or whether there may be other factors that are inhibiting this important aspect of making sense of what pupils find through their inquiries.

Sometimes the problem is class size, time constraints, lack of equipment, etc. The solution is not always in the teacher's hands, but it is important to consider how better class management can ease the difficulties. Reflecting on the organisation and interactions can help to identify aspects which could be changed to improve pupils' opportunities for inquiry.

3. The *Tools for Enhancing Inquiry* across the years of schooling

Chapter coordination: Wynne Harlen

The use of the *Tools for Enhancing Inquiry* can be adapted to the age of the pupils and the stage of development of their inquiry skills.

3.1 Inquiry skills across the years of schooling

The gradual development of understanding in science that we aim for in inquiry-based science education depends on pupils using inquiry skills and competences that are employed by scientists such as raising questions, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions and discussing results. Of course, as experience and research show, children do not at first use these skills in this way. This often means that they retain their preconceived naïve ideas by not testing these ideas rigorously or ignoring conflicting evidence[5]. As well as being important goals that will enable continued learning, inquiry skills have a crucial role in the development of scientific concepts; hence the importance given to helping pupils to develop inquiry skills.

3.1.1 Development of inquiry skills

Fully 'scientific' inquiry skills are not acquired all at once; there is a progression in their use and development from the early years to the middle years of schooling. During this time there are general trends in progression in skills, along three dimensions:

- *Greater elaboration in the use of the skill*. For example, from being able to make a limited suggestion about what might happen to being able make a prediction based on an explicit hypothesis.
- *Wider application in unfamiliar situations.* For example, from being able to plan a fair test about the bounciness of balls to being able to do this when the subject is not so familiar.
- *More conscious awareness of and reflection on the process*. For example, from finding an answer to a question but not being able to explain it, to consciously reflecting on the thinking and reasoning in arriving at the answer.

Thus, the meaning of 'inquiry skills' in practise will vary according to where pupils are in the progression. Although it is useful to have in mind these overall trends, it is also necessary to consider the progression in different skills across the years of schooling, enabling teachers to focus on what is most appropriately developed at various stages. For this purpose it is useful to consider the skills and competences in the following four groups. For each group of skills, the corresponding items in the *Tools for Enhancing Inquiry* are listed.

For each group of skills, the corresponding items in the forms of the *Tools for Enhancing Inquiry* (Annexes 1 and 2) are listed in the following sections.

5 For a further discussion on what it means to learn science through inquiry, please refer to Chapter 3 of the Fibonacci Background booklet *Inquiry in Science Education*, available at www.fibonacci-project.eu, in the *Resources* section.

3.1.2 Group A: Skills concerned with social interaction

Inquiry skills concerned with social interaction	Related items of *Tools for Enhancing Inquiry*
working with others	5a, 5b
reporting orally	5c,
attending to what others find	5e, 5d

Collaboration with others means readiness to work together towards a common goal. In a restricted sense it means sharing materials, working in harmony beside others but not with them. In a fuller sense it involves a discourse among equals, the pooling of ideas, talents and abilities to achieve something which would not have been possible without a combined effort. It is important to pupils' cognitive as well as their social education to encourage them to work with, as opposed to only beside, others. Learning from others is a skill that is needed throughout life and involves developing willingness to listen and respond to others and to share ideas, attention and responsibility.

Children in the early years tend to see things from one point of view – their own – and only gradually come to appreciate that others may see and interpret things differently. The ability to see a situation from several points of view is important in developing a more complete picture of what is happening; it is fostered if children work together and have to understand each others' ideas. In kindergarten this requires some structure set by the teachers to encourage children to listen to and respond to what others say. In the lower primary years children may take assigned roles in a shared activity. Gradually a more mature form of collaboration develops when the children see for themselves the value of working with others. Collaboration then comes from within the child rather than from an external requirement. They organise, negotiate and seek agreed solutions in relation to the process and outcomes of their activities.

3.1.3 Group B: Skills concerned with gathering information about the surrounding world

Inquiry skills concerned with gathering information about the surrounding world	Related items form the *Tools for Enhancing Inquiry*
questioning	2a, 2b, 4a
observing	2f, 2g, 4f, 4g
measuring	2f, 2g, 4f, 4g
planning and conducting investigations	2c, 2d, 2e, 2g, 4c, 4d, 4e, 4f

These are skills that are involved in interacting with things in the real world in order to question, explore and find out about them. This interaction is part of scientific inquiry, which is not complete until the information revealed is analysed, interpreted and explained, using skills considered in Group C below. Questioning is relevant at all stages of conducting an investigation, but particularly at the start. Young children ask all kinds of questions and, by being encouraged to do something to try to answer them, they will come to realise that many questions need to be reformulated so that they can be answered through investigation. Further development leads to recognition that different kinds of questions require different kinds of investigation.

Skills of collecting evidence through observation gradually become more refined as children increasingly pay attention to relevant detail and use measuring instruments and other equipment to refine their observations. They realise when controls are needed in an investigation and can set up a fair test where appropriate – at first using a framework of questions and later through their own planning. They also progress in taking steps to ensure that results are as accurate as possible and repeat measurements where appropriate.

3.1.4 Group C: Skills concerned with analysing and reasoning

Inquiry skills concerned with analysing and reasoning	Related items from the *Tools for Enhancing Inquiry*
testing predictions	3c, 4g
drawing conclusions	3a, 3b, 3e, 3f, 3g, 4h
explaining	3d, 4i

These skills are used in making sense of what is found as a result of questioning, planning and collecting evidence. Analysing and concluding are often neglected, with activities terminating after a statement of 'results' rather than proceeding to trying to explain and understand what was found in terms of scientific ideas. In the early stages of developing these skills children may make predictions about what they expect to happen and then compare what they find with their prediction. They may notice patterns in their observations from which they draw simple conclusions. The skills gradually become more developed as children's investigations become more varied and they use patterns and other data to draw conclusions.

Explaining findings in terms of scientific ideas has a key role in using inquiry to develop children's understanding. They may use words or drawings to represent, or model, their ideas about what explains the events or phenomena under study. Progression shows in the care taken to ensure that conclusions are consistent with all the data and in recognising that there may be more than one explanation that fits the data.

3.1.5 Group D: Skills concerned with communicating

Inquiry skills concerned with communicating	Related items from the *Tools for Enhancing Inquiry*
writing	2g, 6a, 7a-7f
speaking	4i, 5b, 5c, 5e
listening	5b, 5d, 5e
arguing	4i, 5b, 5e
evaluating	2f, 3e, 3f, 3g

These skills are grouped together because it is through attempting to make things understandable to others, or defending a point of view using evidence, that learners examine their ideas critically. Communication is two-way: on one hand, pupils using speech, writing, drawing or modelling to share their ideas; on the other hand, paying attention to information or arguments from others. Effective communication requires the use of appropriate vocabulary and knowledge of conventions for communicating information such as through symbols, graphs and tables.

During the time that they are learning to read and write, children in the early years communicate their observations and findings in science through drawing and talking, gradually beginning to use appropriate words and annotating their drawings with the help of the teacher. Once able to read they can find information from simple texts as well as from illustrations. They progress to recording their observations and data systematically, becoming more able to select the most suitable form. They show understanding of scientific terms and use these in explaining their conclusions. They question each other about their conclusions and identify weaknesses in their own and others' arguments.

3.2 Using the *Tools for Enhancing Inquiry* across the stages of school

The items in the *Tools for Enhancing Inquiry* were designed to capture the inquiry skills described in the previous section for pupils and the corresponding teacher actions that give pupils the opportunities and encouragement to develop these skills across the years of schooling. However, to be most useful in providing information about practise and how it could be improved in a particular case, the statements need to be matched to the pupils' stage of development. Moreover, the activities of the teacher and pupils at each stage of schooling should be cumulative, ensuring that a firm foundation is laid at an earlier stage for further progress.

This raises the question of the extent to which the inquiry skills to be prioritised change or remain the same across the years. Extensive trialling of the tools in classes from kindergarten to middle school enabled this question to be explored. For each stage of schooling (kindergarten, primary, and middle school), particular attention was paid to items systematically recorded by observers as being 'not applicable', and to those which seemed most significant for the age group. The 'not applicable' items were considered in relation to whether the reason was that they were beyond the capability of the children due to their cognitive development, or whether there were circumstances in which they would be potentially applicable. Thus, for each age group, it was not the intention to restrict the *Tools for Enhancing Inquiry* to activities which the children are already capable of undertaking comfortably (their zone of actual development) but to include activities they might accomplish with support (their zone of potential development).

In the following sections, the items from the *Tools for Enhancing Inquiry* found to be a priority for each age group, as well as those found to be beyond the reach of each age group, are presented and discussed in relation to the cognitive development of children across the years. These results and their analysis provide an idea of what inquiry-based teaching and learning looks like at the different levels of schooling.

For each level of schooling, priority items and items that are out of reach for the pupils of that age-range are identified and analysed in the following sections.

3.2.1 Kindergarten (ages 4-6): basic and guided inquiry

Including inquiry-based science activities in kindergarten enables children to begin to develop the skills of investigating and making sense of events and phenomena in the world around them. The cognitive development of children in these early years means that we have to accept that not all aspects of inquiry are within their reach. Of the four groups of skills mentioned in the previous section, generally it is the *skills concerned with gathering information about the surrounding world* (Group B) which are most available to pre-school children. However, it is important not to restrict children to using the most accessible skills, but to help them to develop the *skills concerned with social interaction* (Group A) and with *communicating* (Group D) and the *skills concerned with analysing and reasoning* (Group C) that are required for developing understanding through inquiry.

During the trial of the tools, when the primary and middle school form was used across the range from kindergarten to middle school, nine items were identified as being out of reach for kindergartners. Although it is useful for kindergarten teachers to see the items related to more advanced aspects of inquiry that are appropriate only for older pupils, on balance it is more useful to have a tool that is tailored specifically to the teacher and pupil activities in kindergarten. Thus, specific forms for using the *Diagnostic Tool for CPD Providers* in kindergarten and the *Self-Reflection Tool for Teachers* were developed. These can be found in **ANNEX 3** and **ANNEX 4** respectively.

In order for the progression in inquiry skills from kindergarten to primary school to be clearly identifiable, item numbers in the kindergarten form correspond to item numbers in the primary and middle school forms, even though items and examples of good practise are adapted to kindergarten children. Since items out of reach for kindergartners were excluded from this form, item numbering on these forms is not always consecutive. These forms convey a very basic form of inquiry, in which children are closely guided by the teacher. **Box 2** presents the priority items for kindergarten and explains in more detail how they can be adapted to the needs of preschool children.

Box 2

Using the tools in kindergarten

> Priority items for kindergartners:

- *Items 1a – 1c: building on Ps' ideas.* Talking about the ideas of a particular object or event helps the pupils to identify questions as their own. It also encourages children to use their previous experience in the exploration of new objects and events.
- *Item 4a: pursuing investigable questions introduced by T.* Children's questions should be encouraged but these should gradually become relevant to the topic under study, so that the investigable question introduced by the teacher is felt by the children as being their own. Children have to be helped to maintain their focus on the inquiry question and not be distracted by stimuli encountered in the process of the inquiry.
- *Item 2c: making predictions.* Although preschool children are not able to construct hypotheses anchored in stable knowledge, they should become accustomed to making predictions based on their previous experience. In the early years it is it is important to give attention to distinguishing between predictions and guesses. They will gradually realise that a well argued prediction can help them in drawing appropriate conclusions from their inquiries.
- *Items 2f, 4e, 4h, 4i: investigating.* Preschool children are usually not able to propose the whole procedure for an investigation, but should be helped to plan how to find out if their prediction can be verified. In this way they will begin to realise that investigations are not given but created to answer questions and solve problems.
- *Items 3a, 3c, 3d: drawing conclusions*. Where children have been through the whole process of an investigation and have achieved some result, it is important that they come to some conclusion about the inquiry question and recognise that this has to be based on the evidence collected.
- *Item 6a: making records.* Although preschool children are not able to read and write fluently, they can still be helped to record what they find as a basis for drawing a conclusion. This can be done through drawing or worksheets prepared by the teacher.
- *Items 5a-5e: working with others.* A well-known characteristic of preschool children is their egocentrism, meaning that they do not naturally consider other points of view than their own or share their ideas and preconceptions with others. Kindergarten teachers can help children to do this, for example, by repeating what children say and asking them to listen to and comment on what others say. Thus, through examples, they can experience the benefits of cooperation with others.

> Items beyond the reach of kindergartners:

Since many items are out of reach for kindergartners, **ANNEX 3** and **ANNEX 4** present a specific form for using the *Tools for Enhancing Inquiry* in kindergarten. Progression in inquiry skills from kindergarten to primary school is easily identifiable since item numbers correspond in both forms.

3.2.2 Primary school (ages 6-11): increasingly open inquiry and concrete thinking

The primary school years comprise the longest section of the age span considered when the items in the *Tools for Enhancing Inquiry* were being developed. The items were therefore designed specifically to apply to the period of development in which pupils gradually move from being characteristically egocentric to being able to take account of another's point of view; from learning through action and thinking through doing – typical of the kindergarten child – towards learning through formal thinking and mental manipulation of ideas, which for most will be achieved later in the middle or high school years. The trials and evaluation of the *Tools for Enhancing Inquiry* confirmed that the items were well-suited to primary school science: as it can be seen in **Box 3**, all items were found to be applicable, with the one exception of the pupil activity relating to making some personal notes during their work: it is exceptional for primary children to keep spontaneous notes during the course of their work.

In the primary school years, children develop the ability to think through problems and manipulate things mentally as long as they are 'concrete', meaning that they have some reality for them. There is an increasing ability to share, cooperate and communicate with others and the development of reasoning about cause and effect. Skills relating to gathering information about the surrounding world through investigation are also becoming more developed. Pupils are able to consider variables and set up fair tests where appropriate, first with help and later more independently. They are more likely to use these skills effectively when the investigation concerns familiar objects and events than when the subject matter is unfamiliar. Thus the best way for teachers to help pupils to advance their inquiry skills is through trying to answer a question that the pupils have raised or have identified as their own. Once established as a way of answering questions about the surrounding world, the application of inquiry skills should be extended to developing their knowledge and understanding more widely.

There are limitations in thinking, however, arising particularly from being able to mentally manipulate only things that are real and can be perceived through the senses rather than what is abstract or hypothetical. This has implications for the ability to generalise and draw conclusions from observations. But the limitations are also the challenges, since if more advanced skills and thinking are to be developed it is important that children have opportunities and encouragement to think about what their observations may mean when considered together and how they might be explained. Further, in the later primary years, pupils should be helped to stand back from and reflect on how they conducted their investigation and how it could have been improved, as well as on the results. This encourages the more abstract thinking required in middle and high school science. Thus the *skills concerned with analysing and reasoning* (Group C) increasingly become the focus at the same time as consolidating the *skills concerned with gathering information about the world around* (Group B).

Pupils who may not have had the benefit of some early inquiry-based science activities in kindergarten, and others not yet able to read and write fluently, are likely to require particular help in lower primary school. It is not surprising, then, that there is a considerable overlap between the items considered as priority in kindergarten teaching and those included as priority for primary teaching (see **Box 2** and **Box 3**). As well as learning to communicate through writing, spoken language has an important role in the development of children's thinking. It is important for pupils to be engaged in talk that explores their thinking and enables them to explain their ideas and to hear what others have to say. Thus the items relating to *skills concerned with social interaction* (group A), noted as being most appropriate for emphasis in kindergarten, remain important in the early primary years.

Overall, then, it can be seen both from theoretical considerations of pupils' cognitive development and from the evaluation of classroom trials that, with one exception, all the items in the *Tools for Enhancing Inquiry* are relevant in the primary years. Pupils should become increasingly autonomous in their use of inquiry skills, thus practising a much more open form of inquiry than in kindergarten; nevertheless, concrete thinking – in other words, thinking based on information recovered through the senses – should be a fundamental component of this increasingly open form of inquiry.

Box 3

Using the tools in primary school

> Priority items for primary school:

- *Items 1a and 1b: building on Ps' ideas.* Once established as a way of answering questions about the world around them, the application of inquiry skills should be extended to developing their knowledge and understanding more widely.
- *Item 2c, 4b: making predictions.* Pupils are now able to make predictions based on their ideas or on previously acquired knowledge.
- *Item 2a: asking investigable questions*. The best way for teachers to help pupils to advance their inquiry skills is through trying to answer a question that the pupils have raised or have identified as their own. In primary school, pupils should be increasingly capable of raising their own investigable questions.
- *Items 2d, 2e, 4e, 4h, 4i: investigating*. Pupils are now able to consider variables and set up fair tests where appropriate, first with help and later more independently. Reasoning about cause and effect is developing: it is important that pupils are encouraged to think about what their observations may mean when considered together and how they might be explained.
- *Items 3c, 3e, 3g: drawing conclusions*. Particularly in the later primary years, pupils should be helped to stand back from and reflect on how they conducted their investigation and how it could have been improved, as well as on the results. This encourages the more abstract thinking required in middle and high school science.
- *Items 7a-7e: written records*. These items become increasingly important in primary school, where children are learning to read and write fluently. The type of writing that is demanded of pupils in science class, often anchored on concrete experiences, can help pupils who have trouble with written expression to make significant progress.

> Items beyond the reach of primary school children:

- *Item 7f: taking personal notes while working*. It is exceptional for primary children to keep spontaneous notes during the course of their work.

3.2.3 Middle school (ages 11-15): towards abstract reasoning

Trials in middle school classrooms confirmed that the *Tools for Enhancing Inquiry* are well adapted for observing inquiry-based science teaching and learning of pupils 11–15 years of age. As can be seen in **Box 4**, no items are beyond the reach of these pupils.

In their cognitive development pupils in middle schools are making the transition to, or are already operating at, the level of formal and abstract thinking. In relation to *skills concerned with gathering information about the surrounding world* (Group B), they are able to develop and test hypotheses logically – drawing possible conclusions by looking at a set of data and on that basis forming another hypothesis and devising means for testing it. At this stage pupils are able to gather data and seek information in a systematic way. Thus, all the items in the tools concerned with monitoring a systematic approach to the planning of an investigation, conducting the investigation, recording data and taking notes are applicable. Pupils at this stage may have some problems in identifying and controlling variables that are not obvious. They may be able to devise a 'fair test' when the content is simple and familiar but have difficulty in more complex situations. This has to be taken into account in applying items focusing on testing hypotheses by manipulating variables.

Making the transition from concrete to formal operational thinking requires developing *skills of analysis and reasoning* (Group C), which involve abstraction and conceptualisation. Pupils can build basic concepts – such as mass and size – through concrete operations resulting from the mental manipulation of representations of reality. But building a concept such as density – the ratio between mass and volume, which cannot be directly observed – requires some degree of formal thinking, that is, the ability to mentally manipulate concepts to form more abstract concepts. In order to achieve this, pupils must make a transition from thought stimulated by concrete objects to thought stimulated by abstraction.

In the process of conceptual construction, language takes on a function that extends beyond simple communication: it is the very basis of abstraction. Thus, *skills concerned with communicating* (Group D) are crucial in the process of concept formation. Teachers should give pupils enough opportunity to practise and develop talking and writing skills (including taking personal notes), which require the clarification of meaning.

Items that promote abstract reasoning (see **Box 4**) are thus a priority in middle school. Inquiry at this stage should favour conceptual construction, and pupils should be encouraged to reason at a more abstract level than they do during their primary school years. However, pupils' skills at this level strongly depend on previous experience – that is, the amount and quality of inquiry-based teaching and basic skills that pupils have received during their previous years of schooling. If pupils have had either no experience or only limited experience with inquiry before reaching middle school, then emphasis has to be put on items describing activities and skills recommended as essential to gain at the primary level, as discussed in the previous section.

Box 4

Using the tools in middle school

> Priority items for middle school:

Items that promote abstract reasoning and conceptual construction are particularly important in middle school:

- *Item 3c, testing predictions*
- *Items 3a, 3b, 3e, 3f, 3g, 4h, drawing conclusions*
- *Items 3d, 4i: explaining*
- *Items 4i, 5b, 5e: arguing*
- *Items 2f, 3e, 3f, 3g: evaluating*
- *Items 7a-7f: writing*

Nevertheless, practises are very heterogeneous at this level of schooling. Priority items depend mainly on the amount and quality of inquiry-based teaching that pupils received during their past years of schooling, as well as on their mastery of basic skills.

> Items beyond the reach of middle school children:

No items of the tools were found to be beyond the reach of middle school children.

4. Tools with a life of their own: *creative uses of the Tools for Enhancing Inquiry*

Chapter coordination: Kristina Zoldosova

Although the *Tools for Enhancing Inquiry* were initially designed for teacher self-assessment and for formative assessment of CPD practises, consecutive trials of the tools in various European countries have revealed that the tools are also useful for other purposes. Local actors in each country have used them in different ways according to the specific needs of teachers, teacher trainers, and to the conditions set by their specific educational and political systems.

In this chapter are presented a number of creative uses of the *Tools for Enhancing Inquiry* which emerged from the actors in the field, giving the tools a life of their own. Teachers' and trainers' testimonies concerning the use of the tools are presented in boxes. Their testimonies are an invitation to use the *Tools for Enhancing Inquiry* in creative ways, connected with the needs and priorities of each particular national and local context.

4.1 Triggering the creation of teacher peer learning communities

Sharing and exchanging inquiry-based science teaching experiences among teachers has an intense positive impact on its practical implementation[6]. One of the greatest challenges for a country that is starting to introduce a new pedagogy into its educational system on a large scale is creating authentic teacher peer learning communities. In Italy and in Greece, where inquiry-based science teaching was only beginning to be implemented when the *Tools for Enhancing Inquiry* were first used, the tools were a powerful trigger for creating peer learning communities among teachers.

Firstly, as shown in **Box 5**, the use of the tools opened up the classrooms, which were usually closed to external observers. Teachers who had been working in an isolated manner for years started to collaborate.

Box 5

Using the tools to open up closed classrooms (Italy and Greece)

In the Italian as well as the Greek educational systems, teachers' performance in the classroom is not observed or assessed. Observation or assessment of teachers' performance in class occurs only within the framework of specific training programmes or research projects in didactics. Thus, teachers are rarely familiarised with tools and actions concerning formative assessment of teaching practises.

As a consequence, Italian and Greek classrooms are, in general, closed systems: the presence of a stranger (meaning someone different from the teacher and his or her pupils) in the classroom is rare, particularly in middle school (in elementary school, two teachers were often present in one class until recently).

One of the most significant consequences of using the *Tools for Enhancing Inquiry* in Italy and in Greece was that closed classrooms became open. The teachers and students no longer perceived the presence of others in the classroom as an unusual event. Teacher trainers and teachers were thus able to observe the usual class interactions that took place in their colleagues' classroom, rather than interactions set up by the teacher especially for the occasion of their visit.

The end of isolation among teachers stimulated an atmosphere of reciprocal trust and cooperation. Interactions among teachers from different schools and different grades resulted in collective projects, including the development and revision of teaching and learning resources.

6 For details concerning the impact of peer learning communities on the implementation of inquiry-based teaching, and for other ideas on how to trigger their creation, see Chapter 1.4 of the Fibonacci booklet *Setting up, Developing and Expanding a Centre for Science and Mathematics Education*, available at www.fibonacci-project.eu, in the *Resources* section.

Secondly, an original strategy in the use of the tools enabled the process of learning from peers. Teachers observed each others' science lessons in dyads or triads composed of experienced and beginner teachers, who alternated roles between the observer and the observed. Through the use of the tools, experienced teachers identified their colleagues' main training needs and beginner teachers learned from their more experienced colleagues. Their account is rendered in detail in **Box 6**.

Box 6

Using the tools to learn from each other by alternating roles between observer and observed (Italy)

In Italy, the teacher trainer does not exist as an institutional figure. Nevertheless, there is a great heterogeneity among teachers. Some expert teachers have acquired academic titles which allow them to be selected as trainers in the framework of national in-service or pre-service teacher-training programmes financed by the Italian Ministry of Education and Research (MIUR) or by the European Union.

The teachers involved in the Fibonacci Project in Naples were organised in three groups according to their level of expertise: a core group integrated by six trainers, a group of 12 expert teachers, and a group of 24 experimenter teachers, the idea being to promote situations where the least experienced teachers could learn from the most experienced ones. The *Tools for Enhancing Inquiry* were used according to this logic. Dyads or triads of more experienced and less experienced teachers were constituted in order to observe each others' science lessons using the tools. Thus, each teacher continuously changed roles between observer and observed. Trainers had the chance to identify the main weaknesses in their colleagues' inquiry-based teaching practises, and experimenter teachers had the chance to see examples of inquiry-based teaching in practise.

4.2 Supporting a CPD course based on a bottom-up model

As its title clearly states, the *Diagnostic Tool for CPD Providers* was originally conceived to diagnose teachers' training needs in each particular local context, for example when starting a CPD programme from scratch, or when revising a previously existing CPD programme. In Italy, for instance, many successive meetings among teachers who had used the *Tools for Enhancing Inquiry* were held, where the key elements for a training strategy in inquiry-based science teaching adapted to the Italian context were identified. In Greece, the tool was used in order to introduce inquiry-based science teaching in a very concrete and applicable manner at the beginning of a CPD course for preschool teachers.

Swedish CPD providers and teachers proceeded a little differently. The country's long experience in inquiry-based teaching, as well as their teachers' high level of autonomy, allows their professional development scheme to be based on a strict bottom-up model: no formal training strategy is developed at a national level. Rather, each individual teacher decides on the skills he/she needs to develop in order to meet the specific needs of his/her students. **Box 7** describes how the *Tools for Enhancing Inquiry* were used by Swedish teachers as a support to training within this scheme.

Box 7

The tools as a basis for a CPD course based on a bottom-up model (Sweden)

In Sweden, teacher professional development in inquiry-based science education is based on a bottom-up model. This means that the teacher, his or her activities, practical problems and questions, are the starting point for triggering change in the classroom. Within this scheme, the *Tools for Enhancing Inquiry* became an important basis to analyse and develop each teacher's work in their classroom. Using an inquiry-based approach to training, teachers were first asked to identify their own needs and questions: what knowledge and skills do I as a teacher need to acquire in order to meet the needs of my students? Each teacher then used the tools to decide what specific aspects of inquiry-based practise he/she wanted to work on. Then each teacher tried to change his/her classroom practise by engaging pupils in new learning experiences. The impact of their actions was then discussed, as well as the ways in which this new experience had developed their professional knowledge and skills.

4.3 Planning science lessons

The *Self-Reflection Tool for Teachers* was originally designed for teachers to assess their own teaching practises – in other words, to reflect on past events that took place in their classrooms. This exercise is particularly rich for teachers who are beginning their incursion into inquiry-based science teaching, for it helps to interiorise its principles by drawing their attention to particular aspects of their teaching practise that they need to change. In Slovakia, inquiry-based science teaching has been progressively introduced since the 1990s and is now fully integrated into the national curriculum. Although inquiry-based teaching has advanced slowly due mainly to a very conservative school system, some teachers have been doing inquiry-based teaching for years and are thus in a phase of perfecting their practise. The *Self-Reflection Tool* was used by those expert teachers to prepare their science lessons on new subjects that they had not previously taught, or including new activities that they had not previously trialled with their students. As one Slovak teacher trainer put it, in this context the *Self-Reflection Tool* "supports the teachers in their continuing effort for self-improvement and guarantees the survival of inquiry-based teaching over time, even after formal training is over". In **Box 8**, Slovak teachers who used the *Self-Reflection Tool* to plan their lessons explain how and why it was useful.

Box 8

Using the tools to plan science lessons: testimonies from expert teachers (Slovakia)

- "I used the tool to check my preparation for a lesson. It often happened that after reading it, I added or changed prepared questions and altered the guides for the children. It seems to me that with the help of the tool I am becoming more confident in implementing this way of teaching and I am still finding out what works best for me and for my students." (A kindergarten teacher)
- "The tool gave me ideas on how to lead and support children's activities in order to get them where I wanted to get them." (A primary school teacher)
- "I used the tool to prepare my lessons. Thanks to it I have gradually eliminated some minor problems and I have improved the following lessons." (A high school teacher)

4.4 Developing and improving pedagogical resources

Both in Italy and in Slovakia, the *Tools for Enhancing Inquiry* provided a useful basis for developing and improving pedagogical resources. In a general manner, the tools provided a checklist that allowed teachers and trainers to make sure that all important aspects of inquiry-based teaching and learning were present in the activities suggested in the pedagogical resources. They were also useful for including examples of good practise in the resources. In **Box 9**, Slovak CPD providers explain how the tools helped them to significantly improve their pedagogical resources.

Box 9

Using the tools to improve pedagogical resources intended for beginner teachers (Slovakia)

"As CPD providers, we had engaged in a process of revising the pedagogical resources for our beginner teachers. The frequent use of the *Diagnostic Tool for CPD Providers* was extremely helpful in this process. The following are some examples of how we used the tools to revise the resources:

- Observing classes with the tool reminded us of the aspects of inquiry that are most important for students of each age group and that thus needed to be addressed by the pedagogical resources that we were reviewing. For instance, we became aware that the activities for our 5-7 year-old pupils were lacking predicting and fair testing and that these aspects of inquiry should be included, even if in a basic form.
- The list of items from *Section A* of the tool helped us to include within the resources indications of suitable actions by teachers that could guide pupils' work towards authentic inquiry.
- The examples provided by the tool, as well as our constant observations of inquiry-based science lessons and the valuable feedback given by teachers, allowed us to develop a large pool of concrete examples from practise that we used for enriching the activities described in the resources." (A CPD provider)

Another rather ingenious use of the *Tools for Enhancing Inquiry* was thought up by Italian teachers from comprehensive institutes, big schools uniting both elementary and middle school. These teachers used the tools to observe classes on the same science subject taught in different grade levels. This helped them to identify the key elements in the progressive understanding of particular scientific concepts by pupils of different ages. They used this information to improve their pedagogical resources. Their testimony is presented in **Box 10**.

Box 10

Using the tools to observe the same subject taught at different grade levels helps teachers to improve their pedagogical resources (Italy)

Italian comprehensive institutes are big educational institutions in which both elementary and middle schools coexist. The comprehensive institutes are particularly interested in what they call 'vertical observation' of classroom practises, meaning observing classes of different grade levels where the same science subject is being taught. Thus, the evolution of the complexity of the treatment of the science subject can be discussed and analysed.

In the comprehensive institutes where the *Tools for Enhancing Inquiry* were used, the progressive complexity of the treatment of a particular science subject was explored by teachers through observing classes that were working with the same module at different levels of schooling. This experience, added to continuous interaction among teachers of different school levels, triggered also by the use of the tools and by the discussions that followed, allowed teachers to develop an awareness of the specificities of teaching a particular subject in each grade. This awareness led to the development of new pedagogical resources and to the revision of many previously existing ones.

4.5 Conveying the key aspects of inquiry-based teaching and learning to actors concerned with science education

The task of transforming classroom practises in science does not involve only teachers and teacher trainers, but also many other actors in society: policy makers, curriculum designers, potential financers – in the case of private initiatives –, school administrators, the children's parents. In order for a reform to be successful, understanding and sometimes active support from these actors is crucial. The *Tools for Enhancing Inquiry* were used in some countries to help convey the meaning and the need for inquiry-based teaching and learning in science to some of these key actors.

Slovak teachers who were attempting to introduce inquiry-based science in their classrooms found that their pupils' parents could be an obstacle to their efforts when they did not fully understand the purpose and the principles of this new approach. They used the *Tools for Enhancing Inquiry* to explain to parents what was going on in their children's new science class. Their testimonies are presented in **Box 11**.

Box 11

Using the tools to convey to parents the meaning of inquiry-based science education (Slovakia)

In Slovakia, the main principles of inquiry-based teaching and learning in science are present in all levels of the national curriculum. Nevertheless, changes in teaching practises advance slowly. This is due in part to the conservative attitudes of many actors concerned with science education. When parents become familiarised with inquiry-based teaching and learning, they are more willing to support the teacher in his/her endeavour or, at least, they do not hinder it. Some schools used the *Tools for Enhancing Inquiry* in order to include a definition of inquiry-based science education in their school curriculum, so that parents could be informed of the changes. Others used the tools to inform the parents directly about what was going on in their children's science class, as in the case of these two teachers:

- "The tool helped us to explain to parents what we do with children during science lessons. We have it on a public board so that parents can always can take a look." (A kindergarten teacher)
- "It is very important to explain to parents the goals of inquiry-based science activities, because they are quite different from traditional science activities. We try to avoid misunderstandings concerning pupils' homework and outcomes from science lessons. The tools helped us to explain to parents the purpose and spirit of inquiry-based science activities." (A primary school teacher)

Slovak teachers also found that the tools could be a powerful means of communication between teachers and teacher trainers. It is difficult to convey a precise message of what inquiry-based science teaching is to a teacher who has never been confronted with it. **Box 12** presents the testimony of an experienced teacher who used the *Tools for Enhancing Inquiry* to introduce her colleagues to the main principles of inquiry-based science teaching.

Box 12

Testimony from a teacher who used the tools to introduce colleagues to inquiry-based science teaching (Slovakia)

"When my colleagues wanted to come to my lesson, I gave them the *Diagnostic Tool for CPD Providers* and explained that there they would find the basic principles of the lesson. I found that the tool helped teachers who know nothing about inquiry-based science education to better understand what was going on while observing my lesson. The tool was of great help for me as well after the lesson, when I explained to them what they had seen and why I had proceeded the way I had." (A primary school teacher)

Slovak teacher trainers also used the *Tools for Enhancing Inquiry* to produce promotional materials on inquiry-based science education addressed to local educational authorities. In **Box 13** they explain how they went about it.

Box 13

Using the tools for preparing promotional materials on inquiry-based science education (Slovakia)

"We included the tools in a promotional package on inquiry-based science education for local educational authorities. The tool clarifies what the inquiry-based approach concentrates on, what we expect pupils to accomplish, and the different stages of the process. Therefore we found it was a useful component of that promotional package." (A teacher trainer)

4.6 Supporting curricular development

Slovak and Swedish researchers involved in the trials of the *Tools for Enhancing Inquiry* were also involved in projects in their respective countries that aimed at reforming science teaching at a national level. Slovak researchers found the tools useful in the process of defining the new goals for science education together with national curriculum designers who were not familiar with inquiry-based science education. Their account is rendered in **Box 14**.

Box 14

Using the tools to review the national science curriculum and to prepare the supporting documents (Slovakia)

In view of the positive results it obtained in the implementation of inquiry-based science education, the National Curriculum Team asked the Slovakian Fibonacci team to cooperate in the process of re-designing the national curriculum for science education in ISCED levels 1 and 2. The *Tools for Enhancing Inquiry in Science Education* helped the Fibonacci team members to explain to the members of the National Curriculum Team what inquiry-based science education is, and helped define the main national goals of science education which now will be common to the preschool, primary, and lower secondary levels.

Swedish researchers, on the other hand, decided to explicitly link the *Tools for Enhancing Inquiry* to their new science curriculum in order to encourage teachers and trainers to use them to assess and enhance the implementation of the new curriculum. A more detailed account of this use of the tools can be found in **Box 15**.

Box 15

Using the tools to foster the implementation of a new national science curriculum (Sweden)

The Swedish school system has undergone big changes in a short time: a reformed pre-service education for teachers, a new grading system, and a new curriculum of which inquiry-based science education is a central component.

We have produced a document that compares point by point the *Tools for Enhancing Inquiry* and the new science curriculum, and shows that the tools are entirely compatible with the curriculum. With this document we intend to promote the use of the tools by teachers in the process of implementing the new curriculum. In this manner, the *Diagnostic Tool for CPD Providers* and the *Self-Reflection Tool for Teachers* become respectively, in the Swedish context, a tool for assessing the implementation of the new science curriculum, and a tool for enhancing the development of the competences needed to teach the new curriculum.

4.7 Supporting formative assessment of student learning in science

Swedish teachers used the *Tools for Enhancing Inquiry* to help pupils and their parents understand the goals of inquiry-based science learning and to spell out each pupil's performance with respect to these goals, thus promoting formative assessment of student learning. Formative assessment shares with inquiry the aim of developing understanding through learners taking charge of their learning. It involves teachers and pupils gathering evidence about learning as it takes place and using it to identify appropriate next steps towards the goals of the work and decisions about how to take them. Formative assessment is also central to enabling pupils to acquire ownership of their learning. Ownership requires that pupils know the goals of their work and the quality criteria to be applied so that they can themselves assess where they are in relation to the goals. Details of how the tools were used to promote formative assessment of student learning are given in **Box 16**.

Box 16

Using the tools to discuss with children and their parents their progression in science (Sweden)

In Sweden, the *Tools for Enhancing Inquiry* were used by teachers to support formative assessment of student learning in science. Some teachers used them to discuss with each pupil the goals of the new science curriculum and their personal progress with relation to these goals. This enabled pupils to gain ownership of their learning. The tools were also used as a basis for discussing with pupils' parents their children's performance in science. Pupils were also present in these discussions. The tools helped the teacher give parents a more precise picture of their children's inquiry skills, and thus helped parents and children to identify the skills that needed improvement. The parents found the tool very useful.

4.8 Doing action research

Although the *Tools for Enhancing Inquiry* were not designed for research purposes, they were built on the basis of a back-and-forth dialogue between research and practise, and trialled repeatedly for clarity, precision, and pertinence in many different educational contexts. In Sweden and in Slovakia, researchers have found the *Diagnostic Tools for CPD Providers* to be useful in the context of action research.

Swedish researchers used the tool as a basis for comparing the inquiry-based approach to science teaching in three different countries. The tool was considered by the researchers involved to convey a broad enough idea of inquiry to allow the identification of its different expressions in each country (see **Box 17**).

Box 17

Using the tools in a comparative research study (Sweden)

"We are participating in a research project that aims to compare classes of pupils of the same age from Denmark, Sweden and Estonia, when working with a module on food chemistry. The teachers in the study in all three countries are using the same teaching materials. We therefore have the opportunity to follow the same lessons in all the classes participating in the project. The *Diagnostic Tool for CPD Providers* will provide the basic elements for the comparison. We want to see how inquiry-based science education is interpreted in each country: which aspects are believed to be most important? What can we learn from each other about inquiry-based science education?" (A researcher in science education)

Slovak researchers, on the other hand, used the items from the tools to guide discussions within focus groups with teachers. The focus groups aimed at identifying teachers' main difficulties with the implementation of inquiry (see **Box 18**).

Box 18

Using the tools to discuss with children and their parents their progression in science (Sweden)

In Sweden, the *Tools for Enhancing Inquiry* were used by teachers to support formative assessment of student learning in science. Some teachers used them to discuss with each pupil the goals of the new science curriculum and their personal progress with relation to these goals. This enabled pupils to gain ownership of their learning. The tools were also used as a basis for discussing with pupils' parents their children's performance in science. Pupils were also present in these discussions. The tools helped the teacher give parents a more precise picture of their children's inquiry skills, and thus helped parents and children to identify the skills that needed improvement. The parents found the tool very useful.

5. The *Tools for Enhancing Inquiry in Science Education* and inquiry in mathematics

Chapter coordination: Wynne Harlen

Many of the teachers who used the *Tools for Enhancing Inquiry in Science Education* teach at the primary school or at the kindergarten level; as generalists, they also teach mathematics to the children. The question arose whether they could use or adapt the *Tools for Enhancing Inquiry* to help the understanding and implementation of inquiry-based mathematics education.

In this chapter, this question is explored based on a dialogue with researchers in mathematics. The similarities and differences between inquiry-based science education and inquiry-based mathematics education are analysed, and some insights towards possible adaptations of the *Tools for Enhancing Inquiry in Science Education* to inquiry-based mathematics education are put forth.

In the case of science, the tools have helped to develop the understanding of what inquiry means in practise. The value of the approach that is used to diagnose the aspects of inquiry which are or are not being implemented has been shown in repeated trials of the tools. However, the application of this approach to mathematics has not been explored. If this approach were considered to have potential in inquiry-based mathematics education, then the insights provided in this chapter would need to be carefully reviewed, trialled in the classroom, and developed with examples from practise. In other words, this chapter lays the groundwork for a project for adapting the *Tools for Enhancing Inquiry in Science Education* to mathematics education.

5.1 The nature of mathematical and scientific knowledge

As pointed out in the Fibonacci Background booklet *Learning Through Inquiry*, "science and mathematics share the dominant mode of knowledge building through inquiry"[7]. There are, however, fundamental differences between the knowledge constructed – and how it is constructed – in mathematics and in science. Mathematics deals with abstractions (such as numbers, figures, patterns, models) which may emerge from real world situations or from mathematical questions, and the logical relations between these abstract concepts. Science deals with objects and phenomena of the real world, aiming to describe and understand them, both qualitatively and quantitatively, in terms of 'big' or powerful ideas and models. In its quantitative description of the world, science "needs mathematics or other abstract symbols when it hits the limit of what can be expressed using everyday language"[8].

Key differences between the construction of knowledge in science and in mathematics are also described in the booklet *Learning Through Inquiry*:

> "In mathematics, *problems* are considered, and *proof* that some claim is true of false results from a logical demonstration. In science, *facts* and *questions* are considered, and *models* emerge from the process of observing, experimenting, interpreting, and so on."[9]

Thus science and mathematics are distinct and distinctly different forms of knowledge. Nevertheless, in relation to *learning*, inquiry is considered the appropriate approach to education for both. As pointed out in the Fibonacci Background booklet *Inquiry in Mathematics Education*[10], the terminology of inquiry-based learning is

7 Artigue, M., Dillon, J., Harlen, W., Léna, P. (2012). *Learning Through Inquiry*. Fibonacci Project. Available at www.fibonacci-project.eu, in the *Resources* section.
8 *Ibidem*.
9 *Ibidem*.
10 Artigue, M. & Baptist, P. (2012). *Inquiry in Mathematics Education*. Fibonacci Project. Available at www.fibonacci-project.eu, in the *Resources* section.

not as common in mathematics as in science education. Nevertheless, innovation and research in mathematics education have aspired to promote mathematical learning with understanding and enable pupils to experience authentic mathematical activity.

5.2 Inquiry-based education in science and mathematics

Inquiry-based education in science and in mathematics – or indeed in any other knowledge domain – is firmly rooted in what we know about children's learning. Some of the key findings from research in learning are that:

- children are forming ideas about the world around them from birth and will use their own ideas in making sense of new events and phenomena they encounter;
- direct physical action on objects is important for early learning, gradually giving way to reasoning, first about real events and objects and then abstractions;
- children learn best through mental and physical activity, when they work things out through their own thinking in interaction with adults or other children, rather than receiving instruction and information to memorise;
- language, particularly discussion and interaction with others, has an important role to play in forming children's reasoning and ideas.

Inquiry–based education also requires and develops the capabilities widely accepted as much needed by everyone in modern society, including critical thinking, collaborative working, consideration of alternatives and appropriate forms of communication.

When learning science, the aim is for children to build their understanding of the world around them. The kinds of activity that are consistent with effective learning, leading to this understanding, are those built into the *Tools for Enhancing Inquiry*[11]. These activities of pupils include:

- working in collaboration with others to try to find answers to questions about the world around them;
- using their existing ideas and the ideas of others to suggest explanations (hypotheses) and make predictions;
- planning and carrying out investigations;
- gathering and interpreting data from direct observation or from secondary sources;
- drawing conclusions and developing models based on evidence;
- trying to explain what they find, arguing and reasoning;
- communicating effectively about what was found and how it was found.

When learning mathematics, the aim is to build mathematical understanding. The kinds of activity involved here include[12]:

- engaging with problems and questions in order to express them in ways that make them accessible to some mathematical work;
- exploring different solutions;
- envisaging possible solutions and conjecturing;
- building models based on possible relationships;
- testing, explaining, reasoning, arguing and proving;
- connecting, representing and generalising.
- communicating the process of solving and providing proof as well as the solution.

Clearly there are similarities as well as differences between the classroom experiences that foster understanding in science and mathematics.

On the one hand, there are similarities in the importance of engagement with a question or a problem, of collaborative work, of discussion and dialogue, of considering alternative approaches, of critical thinking, of reflection on learning and of communication. But most importantly, in classroom experiences both in inquiry-based science and mathematics, pupils are engaged in answering questions or solving problems to which they do not know the solution and to which they wish to find the answer.

11 These activities are also described, in a more general manner, in the Fibonacci Background Booklet *Inquiry in Science Education*, available at www.fibonacci-project.eu, in the *Resources* section.

12 For a further discussion of the activities involved in building mathematical understanding, see the Fibonacci Background Booklet *Inquiry in Mathematics Education*, available at www.fibonacci-project.eu, in the *Resources* section.

On the other hand, there are differences in the focus of work, how problems or questions are addressed, how solutions are sought, the basis of validation of solutions or answers, and the nature of explanations. Although problem-solving in science and in mathematics both include cyclic processes[13], there is a significant difference in the role of existing ideas that learners bring to the problem or question. Research in science education shows that when students encounter a new phenomenon or object, they try to make sense of it using ideas formed from earlier experience. This starts the inquiry process in which an existing idea is used to make a prediction and tested by seeing if there is evidence to support the prediction or whether it needs to be modified or an alternative tried. In mathematics, the inquiry process starts from known techniques which are adapted, if necessary, and used to explore the problem. The exploration continues in a cycle of trying different techniques, testing the solution given by each to see if it can be disproved, until a solution is found that cannot be contradicted by further exploration.

5.3 Insights for adapting the *Tools for Enhancing Inquiry* to mathematics education

This discussion of what is similar and what is different in mathematics and in science education suggests that there will be some parts of the *Tools for Enhancing Inquiry* which are relevant to mathematics, but others which are not compatible.

Boxes 19 and 20 provide examples of possible adaptations of the items of the *Tools for Enhancing Inquiry* to mathematics. In each case, as for the *Tools for Enhancing Inquiry*, items are expressed so that a positive response indicates some aspects of inquiry-based mathematics education being present. Where it is not present, this may be because the behaviour may not be relevant to the particular problem or the age of the children or because an opportunity for inquiry was missed. So it is important to provide reasons when the behaviour is not observed.

As was mentioned above, neither this approach to diagnosing classroom practises, nor these concrete examples, have been trialled in the classroom. They are only theoretical insights that need to be thoroughly compared to actual practise and developed through real-life examples.

Box 19

Examples of adaptations of teacher-pupil interactions to inquiry-based mathematics

Providing opportunities for mathematical problem solving

The teacher

- provides problems that can be solved in different ways rather than by using an algorithm
- helps pupils to reformulate problems so that they can be solved mathematically
- asks questions requiring pupils to think of different ways of solving a problem
- provides feedback that encourages pupils to try different approaches
- asks pupils to explain their reasons for choosing the best way of solving a problem

Discussing techniques for solving mathematics problems

The teacher

- asks pupils to discuss different ways of solving the problem
- asks pupils to see if alternative approaches give the same solution
- asks pupils to think of other problems that can be solved in the same way
- encourages pupils to develop strategies or models for solving certain kinds of problems
- arranges for pupils to report and discuss their solutions
- encourages pupils to describe the process of arriving at a solution and its proof
- encourages pupils to reflect on what they have done and found.

13 See the Fibonacci Background Booklet *Inquiry in Mathematics Education*, available at www.fibonacci-project.eu, in the *Resources* section.

Box 20

Examples of adaptations of pupil activities to inquiry-based mathematics

Problem-solving

Pupils

- reformulate problems so that they can be solved with mathematics
- suggest different ways of solving a problem
- explore different ways of solving a problem
- use reasoning to decide between ways of solving a problem
- identify patterns in numbers or the properties of objects
- work out for themselves how to solve a problem, not just following an algorithm
- explain and justify their solutions using logical argument
- make links between new and previous problems in providing proof for their solution
- use appropriate representations (drawings, numbers or symbols) in working out how to solve a problem.

Working with others

Pupils

- collaborate when working in groups
- engage in discussions of their problems and solutions.

Recording their work

Pupils

- state the problem in terms that allow it to be solved using mathematics
- provide a narrative describing the processes of solving the problem
- provide a proof for the solution.

6. Annex 1: *Diagnostic Tool for CPD Providers* form (Primary and Middle School)

Diagnostic Tool for CPD Providers – Primary and Middle School

Interview with the Teacher

I. The observer

Ia Name:

Ib Affiliation (what institution do you belong to?):

Ic Profile (teacher, teacher trainer, researcher in education, other):

II. The session

IIa Date of the session (dd/mm/yyyy): | IIb Duration of the session (in min.):

IIc Subject of the session:

IId Short description of main activities of the session:

III. The class

IIIa Country: | IIIb City or town:

IIIc School name:

IIId Students' age range: | IIIe Number of students in the class:

IIIf Weekly time dedicated to science (hours):

IV. The teacher

IVa Name:

IVb Basic studies (name of University degree(s)):

IVc Years of teaching experience: | IVd Years of science teaching experience:

IVe Years of inquiry teaching experience: | IVf Months teaching this group of students:

IVg Hours of formal inquiry training:

IVh Are you or have you been part of a peer learning community on inquiry-based science teaching ?

V. Preparing the science session

Va Is this session part of a sequence? | Vb How many sessions make up this sequence?

Vc Are these sessions linked by a common learning objective? Which one? | Vd What progression is there in this session from the previous one?

Ve Is the study subject part of the national curriculum for this grade?

Vf Were resources used to prepare this session? YES / NO *(List them under the following headings)*

- Vg Resources on scientific content:
- Vh Resources on pedagogy:
- Vi Student books:

Vj What are your particular objectives for this session? *(List them as given by the teacher, under the following headings)*

- Vk Scientific ideas
- Vl Scientific inquiry skills
- Vm Mathematical skills
- Vn Language skills
- Vo Other

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Diagnostic Tool for CPD Providers – Primary and Middle School

Section A: Teacher-Pupil Interactions

	Items *(T = teacher; Ps = pupils)*	Explanations and examples	Evaluation *(Circle your choice)*			Complementary information *(Where necessary, provide evidence to explain or qualify your evaluation)*
1. Building on Ps' ideas	1a T asks questions requiring Ps to give their existing ideas	T's questions include open questions (requiring more than a one-word answer) which probe what Ps are thinking not only at the start but at other times in the activity; e.g. What do you think is the reason?' rather than 'what is the reason?'	yes	no	NA	
	1b T helps pupils to formulate their ideas clearly	T asks Ps to explain their ideas so that others can understand, if necessary asking 'Is this what you mean?', giving them some time, perhaps in small groups, to discuss and clarify what they think.	yes	no	NA	
	1c T provides Ps with positive feedback on how to review or take their ideas further	T responds to Ps' ideas such as by suggesting how they could be investigated in the current activity or later, or by referring to the Ps' ideas at some stage during the investigation asking 'do you still think that…?'	yes	no	NA	
2. Supporting pupils' own investigations	2a T encourages Ps to ask questions	T asks, for example, 'What would you like to know about …?' or has a 'question box' or board where Ps can put questions which are read and taken into account in later discussion.	yes	no	NA	
	2b T helps Ps to formulate productive (investigable) questions	This might be through discussing with Ps the kinds of questions that can lead to investigation and the need to clarify the meaning of words such as 'best' in a question such as 'which is the best shape for a paper aeroplane?'	yes	no	NA	
	2c T encourages Ps to make predictions	T asks Ps to give their ideas about what they think might happen in the investigation and why, for instance 'What do you think will happen if we … or when …? Why do you think that?"	yes	no	NA	
	2d T involves Ps in planning investigations	T makes sure that Ps take part in planning the investigation by providing some structure for making decisions about what they will do. Ps are not expected to plan without help but the plan is not decided entirely by the teacher.	yes	no	NA	
	2e T encourages Ps to include fair testing in their planning	In investigations where comparisons are being made or changes are being investigated, T encourages Ps to think about and ensure that some things are kept the same so that only the variables under investigation change.	yes	no	NA	
	2f T encourages Ps to check their results	T asks Ps to be sure to check their results by repeating observations or measurements where possible and ensuring accuracy, for instance in reading measurement scales carefully.	yes	no	NA	
	2g T helps Ps to keep notes and record results systematically	This might be through providing a framework or headings or a checklist of things to record and where relevant helping them to organise their data in a table.	yes	no	NA	
3. Guiding analysis and conclusions	3a T asks Ps to state their conclusions	T makes it explicit that they should bring their results together in a statement of what they mean, not simply record data collected.	yes	no	NA	
	3b T asks Ps to check that their conclusions fit with their results	T asks Ps to check that all their observations or results are consistent with their overall conclusions.	yes	no	NA	
	3c T asks Ps to compare their conclusions with their predictions	T asks Ps to recall what they predicted and to compare it with what they found.	yes	no	NA	
	3d T asks pupils to give reasons or explanations for what they found	T asks Ps to explain and not merely describe what they found, helping them to use ideas that also can explain other situations. 'What could be the reason for …?'	yes	no	NA	
	3e T helps Ps identify possible sources of error	T asks Ps to consider what aspects of how they carried out the investigation could have made a difference to their results, such as by asking if they would get exactly the same result if the investigation was repeated.	yes	no	NA	
	3f T helps Ps identify new or remaining questions	This could be by asking Ps what else they would like to know about the topic of their investigation and discussing other questions that have arisen.	yes	no	NA	
	3g T encourages Ps to reflect on what they have done and found	This might be by asking Ps 'do you think this was the best way to investigate …?' 'What would you change if you were doing it again?'	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Diagnostic Tool for CPD Providers – Primary and Middle School

Section B: Pupil Activities

	Items *(T = teacher; Ps = pupils)*	Explanation and examples	Evaluation *(Circle your choice)*			Complementary information *(Where necessary, provide evidence to explain or qualify your evaluation)*
4. Carrying out investigations	4a Ps pursue questions which they have identified as their own, even if introduced by the T	Their ownership of the questions is shown by Ps being able to explain in their own words what they are trying to do or find out.	yes	no	NA	
	4b Ps make predictions based on their ideas	They give a reason for what they predict, even if it is inaccurate, showing that is it not just a guess.	yes	no	NA	
	4c Ps take part in planning an investigation	Ps suggest what to do in general terms and discuss details within the structure provided by the teacher. The plan may not be created entirely by Ps but is understood and agreed by them.	yes	no	NA	
	4d Ps include "fair testing" in their plan if appropriate	In investigations where it is necessary to ensure fair comparisons, pupils' plans include decisions about which variables to change and which to keep the same.	yes	no	NA	
	4e Ps carry out their own investigations	Pupils are active in collecting and using evidence themselves (directly from objects studied or using secondary sources), not observing someone else doing this. If this is NO then 4f is also recorded as NO.	yes	no	NA	
	4f Ps gather data using methods and sources appropriate to their inquiry question	The appropriate data may be observations, measurements, or information from secondary sources such as books, posters or websites. For observations and measurements, relevant equipment and instruments such as rulers, balances or lenses are used.	yes	no	NA	
	4g The data gathered enables Ps to test their predictions	The nature of the data collected by observations, measurement, or from secondary sources enables them to test their predictions and answer their inquiry questions.	yes	no	NA	
	4h Ps consider their results in relation to the inquiry question	This refers to group or whole class discussion (the written account is considered separately) of how the results of the investigation help to answer the inquiry question.	yes	no	NA	
	4i Ps propose explanations for their results	Ps discuss in groups or the whole class possible reasons for what they found or how the results can be explained.	yes	no	NA	
5. Working with others	5a Ps collaborate when working in groups	Ps work together, agreeing on tasks and sharing them, not working individually although seated in a group.	yes	no	NA	
	5b Ps engage in discussions of their investigations and explanations	During group work Ps discuss what they are doing and how to explain what they find.	yes	no	NA	
	5c Ps report their work to the class	This can be by direct oral reporting from one or more groups to the whole class, or to another group, or groups displaying their work in the classroom for all to look at.	yes	no	NA	
	5d Ps listen to each other during reporting	The indications of paying attention include looking at the person speaking, not speaking themselves and responding, if asked, to what was reported.	yes	no	NA	
	5e Ps respond to each other during reporting	Responding may imply asking questions to better understand their classmates' presentation or agreeing or disagreeing with what is being reported.	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Diagnostic Tool for CPD Providers – Primary and Middle School

Section C: Pupils' Records

	Items *(T = teacher; Ps = pupils)*	Explanations and examples	Evaluation *(Circle your choice)*			Complementary information *(Where necessary, provide evidence to explain or qualify your evaluation)*
6. Records Ps make of their work	6a Ps make some record of what they did and found	This can be an individual or group record, in the form of a drawing and/or written account, as appropriate to the age group. If there is no tangible record, responses to all items in section 7 ("Ps' written records") will be N/A	yes	no	NA	
7. Ps' written records	7a Records clearly state the problem or question being investigated	In most written records, whether individual or group, there is a title or statement that describes what question the investigation was designed to answer.	yes	no	NA	
	7b Records indicate what data were collected and how	Most written records (individual or group) include a brief statement of what was observed or measured and how this was done. E.g. that the length of the shadow of a stick was measured using a ruler.	yes	no	NA	
	7c Observations and data are recorded in a systematic way	Most records (individual or group) include a table or organised list of data collected or a drawing showing their result.	yes	no	NA	
	7d Records indicate whether or not results agreed with predictions	Most written records state whether what Ps found agreed with what they predicted.	yes	no	NA	
	7e Records indicate what the conclusions were	Most written reports (individual or group) included discussion or a general statement of what the observations or measurements meant overall.	yes	no	NA	
	7f Ps take some personal notes during their work	This refers to informal notes that Ps may have made during the investigation, jotting down ideas or data, not the formal written or oral record compiled at the end.	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

7. Annex 2: *Self-Reflection Tool for Teachers* form (Primary and Middle School)

Self-Reflection Tool for Teachers – Primary and Middle School

Section A: The Teacher's Role

	Items *(T = teacher; Ps = pupils)*	Examples of good practise	Decision			Notes
1. Building on Ps' ideas	**1a** Did you ask questions to reveal and show interest in Ps ideas?	You phrased questions such as 'what do you think is happening?' 'why do you think this might be?' rather than 'what is the reason?' or 'why is this happening?'	yes	no	NA	
	1b Did you help Ps to express their ideas clearly?	You gave Ps time to think about how to express their ideas so that others could understand them; perhaps by giving a short time for discussion in pairs or small groups, or you repeated what they said and asked 'Is this what you mean?'	yes	no	NA	
	1c Did you give Ps positive feedback on how to review or take their ideas further?	You may have suggested how Ps' ideas could be investigated at some stage in the current activity or later; you may have referred to their ideas in later discussion asking ' do you still think that...?'	yes	no	NA	
2. Supporting pupils' own investigations	**2a** Did you encourage Ps to ask questions?	You asked them, for instance, 'What would you like to know about...?' Or provided a 'question box' or board where Ps could post their questions.	yes	no	NA	
	2b Did you help them formulate productive (investigable) questions?	This might be through discussing the kinds of questions that can lead to investigation and which include an indication of what to do and what to look for in order to answer it (i.e.: clarify the meaning of words such as 'best' in a question such as 'which is the best shape for a paper aeroplane?')	yes	no	NA	
	2c Did you ask them to make predictions?	At some stage of discussing an investigation you asked Ps 'What do you think will happen if ... or when...? Why do you think that?"	yes	no	NA	
	2d Did you involve them in planning investigations?	Perhaps you provided a planning framework, or discussed with Ps the possible steps in the investigation, asking for their ideas in relation to parts of the plan so that they regarded it as their own and not planned entirely by you.	yes	no	NA	
	2e Did you encourage them to include fair testing where appropriate?	In investigations where comparisons were being made you prompted them to think about what has to be kept the same and what had to be changed so that only the variable under investigation was changed.	yes	no	NA	
	2f Did you ask them to check their results or observations?	You asked Ps to check their results by repeating their observation or measurements where possible and ensuring accuracy, for instance in reading measurement scales carefully.	yes	no	NA	
	2g Did you help them to keep notes and record results systematically?	This might be through showing Ps how to organise data in a table or suggesting a list of headings or a checklist of items to be included in their report.	yes	no	NA	
3. Guiding analysis and conclusions	**3a** Did you ask Ps to provide some conclusions from their work?	This might be by helping Ps to make some general statement about what they found rather than only listing individual findings; for instance about the factors that were found to make a difference, not just the difference between one condition and another.	yes	no	NA	
	3b Did you ask Ps to check that their conclusions were consistent with their results?	Where Ps gave a conclusion, you asked them to be sure that it fitted all their observations or results.	yes	no	NA	
	3c Did you ask Ps to compare their conclusions with their predictions?	You asked Ps to recall what they predicted and to compare this with their conclusions.	yes	no	NA	
	3d Did you ask Ps to think of reasons or explanations for what they found?	Whether or not there was agreement with predictions, you encouraged Ps to try to explain what was found and develop their understanding of the events or phenomena investigated (i.e., by helping them to use an idea that could also explain other situations).	yes	no	NA	
	3e Did you ask Ps to identify possible sources of error?	You discussed with Ps whether some aspects of the way the investigation was carried out could have affected the result, perhaps by asking if they would get exactly the same result if repeated.	yes	no	NA	
	3f Did you ask Ps to identify further questions?	You encouraged Ps to continue to inquire, perhaps by discussing other questions that arose or asking 'what else would you like to find out about ...?'	yes	no	NA	
	3g Did you encourage Ps to reflect on what they found and how they found it?	You spent some time after the investigation helping Ps to recall what they had done, discuss what they had learned, how they could improve their investigation and apply this in future work.	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Self-Reflection Tool for Teachers – Primary and Middle School

Section B: Pupils' Activities

	Items (T = teacher; Ps = pupils)	Examples of good practise	Decision			Notes
4. Carrying out investigations	4a Did Ps work on questions which they identified as their own, even though introduced by you?	Indicated by being able to explain in their own words what they were trying to do or find out.	yes	no	NA	
	4b Did Ps make predictions based on their ideas?	Ps could give a reason for what they predict, even if it was inaccurate, showing that it was not just a guess.	yes	no	NA	
	4c Did Ps take part in planning an investigation?	Ps suggested in general terms what to do to solve a problem or answer a question even if they needed help with details.	yes	no	NA	
	4d Did Ps include 'fair testing' in their plan if appropriate?	Ps suggested what things to change, what to keep the same for a fair test.	yes	no	NA	
	4e Did Ps carry out an investigation themselves?	Ps were actively involved in collecting information (either from real objects or from secondary sources such as books, posters, websites), not watching others do this.	yes	no	NA	
	4f Did Ps gather data using methods and sources appropriate to the inquiry question?	Ps were making observations, measurements, using appropriate equipment, or gathering evidence in other ways (including secondary sources) that were relevant to the question or problem.	yes	no	NA	
	4g Did the data gathered enable Ps to test their predictions?	The nature of the data collected by observations, measurement, or from secondary sources enabled them to test their predictions and answer their inquiry questions.	yes	no	NA	
	4h Did Ps consider their results in relation to the inquiry question?	In a group or whole class discussion, Ps discussed whether what they found answered the inquiry question.	yes	no	NA	
	4i Did Ps propose explanations for their results?	In a group or whole class discussion, Ps gave possible reasons for what they found even if it did not answer the question being investigated.	yes	no	NA	
5. Working with others	5a Did Ps collaborate with others during group work?	Ps discussed and worked together to agree what to do, not simply working individually although seated in groups.	yes	no	NA	
	5b Did Ps engage in class or group discussions of their investigations and explanations?	For instance, after completing their investigation Ps took part in discussions in groups or as a whole class of what they did and found and how they explained their results.	yes	no	NA	
	5c Did Ps report their work in some form to the whole class?	There was some way in which Ps shared their work with others, either by reporting to a group or the whole class or displaying their records as a poster or artefact.	yes	no	NA	
	5d Did Ps listen to each other during reporting?	Indicated by looking at another who was presenting their work, not speaking themselves, and responding if asked.	yes	no	NA	
	5e Did Ps respond to each other during reporting?	Responding may imply asking questions to better understand their classmates' presentation or agreeing or disagreeing with what is being reported.	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Self-Reflection Tool for Teachers – Primary and Middle School

Section C: Pupils' Records

	Items (T = teacher; Ps = pupils)	Examples of good practise	Decision			Notes
6. Records Ps make of their work	6a Did Ps make some record of what they did and found?	Ps made some collective or individual record of what they did in the form of a drawing or writing or artefact as appropriate to the age group. (Note that if the answer to this questions is No, then it will also be No for the following five questions.)	yes	no	NA	
7. Ps' written records	7a Did Ps include in their record a clear statement of the inquiry question or problem?	Any written group or individual records includes a title or statement that indicates the inquiry question or problem.	yes	no	NA	
	7b Did Ps' records indicate what data were collected and how they were collected?	Any records, either collective or individual, indicate in words or drawings what was observed or measured and how this was done.	yes	no	NA	
	7c Did Ps record observations and data collected in a systematic way?	Any record, either collective or individual, presents data in a table or organised list or show results in the form of a diagram.	yes	no	NA	
	7d Did Ps indicate in their records whether results agreed with their predictions?	Any records, either collective or individual, include a reflection on whether what was found agreed with what they predicted.	yes	no	NA	
	7e Did Ps state their conclusions in their record?	Any records, either collective or individual, include a statement of what was concluded from the investigation, that is, not just the results but what they mean in more general terms.	yes	no	NA	
	7f Did Ps make personal notes during their work?	Indicated by Ps jotting down some personal notes of ideas or data during the investigation, not the formal record made afterwards.	yes	no	NA	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

8. Annex 3: *Diagnostic Tool for CPD Providers* form (Kindergarten)

Diagnostic Tool for CPD Providers – Kindergarten

Interview with the Teacher

I. The observer	Ia Name:	
	Ib Affiliation (what institution do you belong to?):	
	Ic Profile (teacher, teacher trainer, researcher in education, other):	
II. The session	IIa Date of the session (dd/mm/yyyy):	IIb Duration of the session (in min.):
	IIc Subject of the session:	
	IId Short description of main activities of the session:	
III. The class	IIIa Country:	IIIb City or town:
	IIIc School name:	
	IIId Students' age range:	IIIe Number of students in the class:
	IIIf Weekly time dedicated to science (hours):	
IV. The teacher	IVa Name:	
	IVb Basic studies (name of University degree(s)):	
	IVc Years of teaching experience:	IVd Years of science teaching experience:
	IVe Years of inquiry teaching experience:	IVf Months teaching this group of students:
	IVg Hours of formal inquiry training:	
	IVh Are you or have you been part of a peer learning community on inquiry-based science teaching ?	
V. Preparing the science session	Va Is this session part of a sequence?	Vb How many sessions make up this sequence?
	Vc Are these sessions linked by a common learning objective? Which one?	Vd What progression is there in this session from the previous one?
	Ve Is the study subject part of the national curriculum for this grade?	
	Vf Were resources used to prepare this session? YES / NO *(List them under the following headings)*	
	Vg Resources on scientific content:	
	Vh Resources on pedagogy:	
	Vi Student books:	
	Vj What are your particular objectives for this session? *(List them as given by the teacher, under the following headings)*	
	Vk Scientific ideas	
	Vl Scientific inquiry skills	
	Vm Mathematical skills	
	Vn Language skills	
	Vo Other	

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Diagnostic Tool for CPD Providers – Kindergarten

Section A: Teacher-Child Interactions

	Items *(T = teacher; Ch = children)*	Explanations and examples	Evaluation *(Circle your choice)*			Complementary information *(Where necessary, provide evidence to explain or qualify your evaluation)*
1. Building on children's ideas	**1a** T asks questions requiring Ch to give their existing ideas	T's questions include open questions (requiring more than a one-word answer) which probe what Ch are thinking not only at the start but at other times in the activity. E.g. 'What do you think is the reason?' rather than "what is the reason?'.	yes	no	NA	
	1b T helps Ch to formulate their ideas clearly	T asks Ch to explain their ideas so that others can understand, if necessary asking 'is this what you mean?' and giving them some time, perhaps in small groups, to discuss and clarify what they think.	yes	no	NA	
	1c T provides Ch with positive feedback on how to review or take their ideas further	T responds to Ch's ideas by suggesting how they could be investigated in the current activity or later, or by referring to the Ch's ideas at some stage during the investigation asking 'do you still think that…?'	yes	no	NA	
2. Supporting children's investigation	**2a** T encourages Ch to ask questions	T asks, for example, 'What would you like to know about…?'	yes	no	NA	
	2c T encourages Ch to make predictions	T asks Ch to give their ideas about what they think might happen in the investigation, for instance: 'What do you think will happen if we… or when…?'	yes	no	NA	
	2d T involves Ch in planning an investigation	T makes sure that Ch take part in planning the investigation, e.g. by asking questions such as 'How can we find out whether our prediction is correct or not?' Teachers suggest a plan but it should be understood and agreed to by Ch.	yes	no	NA	
	2f T encourages Ch to check their results	T asks Ch to be sure to check their results by repeating observations or measurements where appropriate.	yes	no	NA	
3. Guiding children to conclusions	**3a** T asks Ch to state their conclusions	T makes it explicit that Ch should bring their results together in a statement of 'what we have found out about…'	yes	no	NA	
	3c T asks Ch to compare their conclusions with their predictions	T asks Ch to recall what they predicted and to compare it with what they found.	yes	no	NA	
	3d T asks Ch to give reasons or explanations for what they found	T asks Ch to explain and not merely describe what they found, for example by asking: 'Have you seen something similar before? Can you compare what you found with something you saw before? What could be the reason for…?'	yes	no	NA	
	3f T helps Ch to identify new or remaining questions	This could be by asking Ch what else they would like to know about the topic of their investigation and discussing the questions that have arisen.	yes	no	NA	
5. Guiding children to share ideas	**5a** T encourages Ch to make a group drawing, poster or model of what they have produced.	This could be by asking Ch to prepare, for example, a group poster that involves them putting their ideas together.	yes	no	NA	
	5b T takes notice of the Ch's ideas and encourages Ch to do the same	T uses exact expressions of Ch to highlight the different ideas, avoiding direct comparison (e.g. "S thinks that… B thinks that…").	yes	no	NA	
	5d T encourages Ch to listen to each other	T ensures Ch speak one at a time and pay attention when someone else is speaking.	yes	no	NA	

Item numbers in this form correspond to item numbers in the primary and middle school form. Items out of reach for kindergartners were excluded from this form. Items and their explanations and examples are adapted to kindergarten children. This explains non-consecutive numbering of items on this form.

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Diagnostic Tool for CPD Providers – Kindergarten

Section B: Children's Activities

	Items *(T = teacher; Ch = children)*	Explanations and examples	Evaluation *(Circle your choice)*			Complementary information *(Where necessary, provide evidence to explain or qualify your evaluation)*
4. Carrying out an investigation	**4a** Ch pursue questions which they have identified as their own, even if introduced by the T	Their ownership of the questions is shown by Ch being able to explain in their own words what they are trying to do or find out.	yes	no	NA	
	4b Ch make predictions based on their ideas	They give a reason for what they predict, even if it is inaccurate, showing that it is not just a guess.	yes	no	NA	
	4c Ch take part in planning an investigation	Ch do not need to propose their own plan but comment on the teacher's proposed plan or adapt it during the investigation.	yes	no	NA	
	4e Ch carry out their own investigations	Ch are active in collecting and using evidence themselves, not observing someone else doing this.	yes	no	NA	
	4f Ch gather data using methods and sources appropriate to their inquiry question	The appropriate data may be observations, simple measurements, or information from books.	yes	no	NA	
	4g The data gathered by Ch enable them to test their prediction	The nature of the data collected through observations, measurement, or secondary sources is appropriate for testing Ch's predictions.	yes	no	NA	
	4h Ch consider their results in relation to the inquiry question	In discussion with others and the T, Ch use the observed evidence to answer the inquiry question.	yes	no	NA	
	4i Ch try to give explanations of their results	Ch give possible reasons for what they found or how the results can be explained based on their previous experience and knowledge.	yes	no	NA	
5 and 6. Children's records	**6a** Ch make a simple record of what they did and found	This can be an individual or group record in the form of a drawing with labels or brief writing, or by responding to a worksheet prepared by the T.	yes	no	NA	
	5c Ch share their records of what they did and found with others during reporting to the class	Ch try to find out others' ideas about what they were investigating. They listen to each other.	yes	no	NA	

Item numbers in this form correspond to item numbers in the primary and middle school form. Items out of reach for kindergartners were excluded from this form. Items and their explanations and examples are adapted to kindergarten children. This explains non-consecutive numbering of items on this form.

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

9. Annex 4 : *Self-Reflection Tool for Teachers* form (Kindergarten)

Self-Reflection Tool for Teachers – Kindergarten

Section A: Teacher-Child Interactions

	Items *(T = teacher; Ch = children)*	Examples of good practise	Decision			Notes
1. Building on children's ideas	**1a** Did you ask questions requiring Ch to give their existing ideas?	You asked Ch open questions (requiring more than a one-word answer) which probed what they were thinking, not only at the start but at other times in the activity. E.g. 'What do you think is the reason?' rather than 'what is the reason?'.	yes	no	NA	
	1b Did you help Ch to formulate their ideas clearly?	You asked Ch to explain their ideas so that others could understand, if necessary asking 'is this what you mean?' and giving them some time, perhaps in small groups, to discuss and clarify what they thought.	yes	no	NA	
	1c Did you provide Ch with positive feedback on how to review or take their ideas further?	You responded to Ch's ideas by suggesting how they could be investigated, or referred to the Ch's ideas at some stage during the investigation asking 'do you still think that…?'	yes	no	NA	
2. Supporting children's investigation	**2a** Did you encourage Ch to ask questions?	You asked, for example, 'What would you like to know about…?'	yes	no	NA	
	2c Did you encourage Ch to make predictions?	You asked Ch to give their ideas about what they thought might happen in the investigation, for instance: 'What do you think will happen if we… or when…?'	yes	no	NA	
	2d Did you involve Ch in planning investigations?	You involved Ch in planning the investigation, e.g. by asking questions such as 'How can we find out whether our prediction is correct or not?' You suggested a plan but Ch understood it and agreed to it.	yes	no	NA	
	2f Did you encourage Ch to check their results?	You asked Ch to check their results by repeating observations or measurements where appropriate.	yes	no	NA	
3. Guiding children to conclusions	**3a** Did you ask Ch to state their conclusions?	You explicitly asked Ch to bring their results together, i.e. by asking them 'what have we have found out about…'	yes	no	NA	
	3c Did you ask Ch to compare their conclusions with their predictions?	You asked Ch to recall what they predicted and to compare it with what they found.	yes	no	NA	
	3d Did you ask Ch to give reasons or explanations for what they found?	You asked Ch to explain and not merely describe what they found, for example by asking: 'Have you seen something similar before? Can you compare what you found with something you saw before? What could be the reason for…?'	yes	no	NA	
	3f Did you help Ch to identify new or remaining questions?	This could be by asking Ch what else they would like to know about the topic of their investigation and discussing the questions that have arisen.	yes	no	NA	
5. Guiding children to share ideas	**5a** Did you encourage Ch to make group drawings, posters, or models of what they produced?	This could be by asking Ch to prepare, for example, a group poster that involves them putting their ideas together.	yes	no	NA	
	5b Did you take notice of Ch's ideas and encourage Ch to do the same?	You used Ch's exact expressions to highlight their different ideas, avoiding direct comparison (e.g. 'S thinks that… B thinks that…').	yes	no	NA	
	5d Did you encourage Ch to listen to each other?	You made sure that Ch spoke one at a time and paid attention when someone else was speaking.	yes	no	NA	

Item numbers in this form correspond to item numbers in the primary and middle school form. Items out of reach for kindergartners were excluded from this form. Items and examples of good practise are adapted to kindergarten children. This explains non-consecutive numbering of items on this form.

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

Self-Reflection Tool for Teachers – Kindergarten Section B: Children's Activities						
	Items *(T = teacher; Ch = children)*	Examples of good practise	Decision			Notes
4. Carrying out an investigation	4a Did Ch pursue questions that they identified as their own, even if introduced by you?	Their ownership of the questions is shown by Ch being able to explain in their own words what they are trying to do or find out.	yes	no	NA	
	4b Did Ch make predictions based on their ideas?	They gave a reason for what they predicted, even if it was inaccurate, showing that it was not just a guess.	yes	no	NA	
	4c Did Ch take part in planning the investigation?	Ch do not need to propose their own plan, but make sure they comment on your proposed plan or adapt it during the investigation.	yes	no	NA	
	4e Did Ch carry out their own investigation?	Ch were active in collecting and using evidence themselves, not observing you doing this.	yes	no	NA	
	4f Did Ch gather data using methods and sources appropriate to their inquiry question?	The appropriate data may be observations, simple measurements, or information from books.	yes	no	NA	
	4g Did the data gathered by Ch enable them to test their predictions?	The nature of the data collected through observations, measurement, or secondary sources was appropriate for testing Ch's predictions.	yes	no	NA	
	4h Did Ch consider their results in relation to the inquiry question?	In discussion with others and with you, Ch used the observed evidence to answer the inquiry question.	yes	no	NA	
	4i Did Ch try to give explanations of their results?	Ch gave possible reasons for what they found or how the results could be explained based on their previous experience and knowledge.	yes	no	NA	
5 and 6. Children's records	6a Did Ch make a simple record of what they did and found?	This can be an individual or group record in the form of a drawing with labels or brief writing, or by responding to a worksheet that you prepared.	yes	no	NA	
	5c Did Ch share their records of what they did and found with others during reporting to the class?	Ch tried to find out others' ideas about what they were investigating. They listened to each other.	yes	no	NA	

Item numbers in this form correspond to item numbers in the primary and middle school form. Items out of reach for kindergartners were excluded from this form. Items and examples of good practise are adapted to kindergarten children. This explains non-consecutive numbering of items on this form.

PLEASE READ THE INSTRUCTIONS CAREFULLY BEFORE USING THIS TOOL

10. Bibliography

Appleton, K. (2008). Developing Science Pedagogical Content Knowledge Through Mentoring Elementary Teachers. *Journal of Science Teacher Education*, 19, 523-545.

Artigue, M. & Baptist, P. (2012). *Inquiry in Mathematics Education*. Fibonacci Project (available at www.fibonacci-project.eu).

Artigue, M., Dillon, J., Harlen, W. & Léna, P. (2012). *Learning Through Inquiry*. Fibonacci Project (available at www.fibonacci-project.eu).

Beerer, K. & Bodzin, A. (2004). Promoting inquiry-based science instruction: The validation of the Science Teacher Inquiry Rubric (STIR). Paper presented at the Annual Meeting of the Association for Science Teacher Education, Nashville, TN.

Borda Carulla, S., Heinze, S. & Skiebe-Corrette, P. (eds.) (2012). *Setting up, Developing and Expanding a Centre in Science and Mathematics Education*. Fibonacci Project (available at www.fibonacci-project.eu).

Bransford, J., Brown, A. & Cocking, R. (eds.) (2000). *How People Learn*. Washington, D.C.: National Academy Press.

Crawford, B. (2000). Embracing the Essence of Inquiry: New Roles for Science Teachers. *Journal of Research in Science Teaching*, Vol. 37, No. 9, 916-937.

Delclaux, M. & Saltiel, E. (2011). An evaluation of local teacher support strategies for the implementation of inquiry-based science education in French primary schools. *Education 3-13*, DOI:10.1080/03004279.2011.564198.

Duschl, R. A., Schweingruber H.A. and Shouse, A.W. (eds.) (2007). *Taking Science to School: Learning and Teaching Science in Grades K-8.* Washington DC: The National Academies Press.

Garrison, L. & Amaral, O. (2006). Designing and Using Program-specific Evaluation Instruments. *Electronic Journal of Science Education*, Vol. 11, No. 1. Retrieved 24 March 2010 from http://ejse.southwestern.edu

Harlen, W. (2012). *Inquiry in Science Education*. Fibonacci Project (available at www.fibonacci-project.eu)

Harlen, W. (2010). *Principles and Big ideas of Science Education*. Hatfield, UK: ASE. Retrieved 20 September 2012, from http://cmaste.ualberta.ca/en/Outreach/~/media/cmaste/Documents/Outreach/IANASInterAmericasInquiry/PrinciplesBigIdeasInSciEd.pdf

Harlen, W. (2009). Teaching and learning science for a better future. *School Science Review*, 90 (933), 33-41.

Harlen, W. & Allende, J. (2009). *Report of the Working Group on Teacher Professional Development in Pre-Secondary School Inquiry-Based Science Education*. Santiago, Chile: IAP.

Harlen, W. (2004). Evaluating Inquiry-based Science Developments. A paper commissioned by the National Research Council in preparation for a meeting on the status of evaluation of Inquiry-Based Science Education, 11 May 2004.

Horizon Research (2003). 2003–04 *Core Evaluation Manual: Classroom Observation Protocol*. Retrieved 3 November 2009 from http://www.horizon-research.com/instruments/clas/cop.php

Horizon Research (2000). *Inside the Classroom: Observation and Analytic Protocol*. Retrieved 31 March 2010 from http://www.horizon-research.com/instruments/clas/cop.pdf

IAP (2011). *Taking IBSE into Secondary Education. Report of a conference held in York, UK, October 2010.* Available at http://www.fasas.org.au/downloads/YorkIBSEConference2010Report.pdf

Minner, D., Jurist Levy, A., Century, J. (2010). Inquiry-Based Science Instruction – What Is It and Does It Matter? Results from a Research Synthesis Years 1984 to 2002. *Journal of Research in Science Teaching*, Vol. 47, No. 4, 474-476.

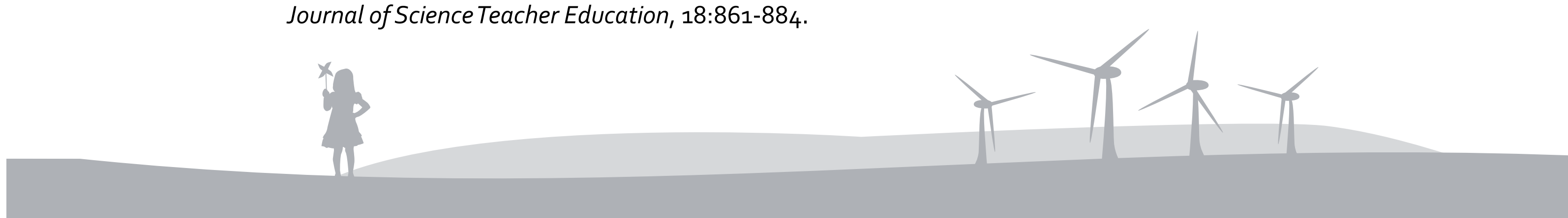
National Research Council (2008). *Taking Science to School. Learning and Teaching Science in Grades K-8.* Washington D.C.: The National Academies Press.

Saltiel, E. (2006). *Methodological guide. Inquiry-Based Science Education: Applying it in the Classroom*. Pollen Project. Retrieved on 24 March 2010 from http://www.pollen-europa.net/?page=%2Bag%2BXQhDnho%3D

Sawanda, D., Piburn, M., Judson, E., Turley, J., Falconer, K., Benford, R. & Bloom, I. (2002). Measuring Reform Practices in Science and Mathematics Classrooms: The Reformed Teaching Observation Protocol, in *School Science and Mathematics*, Vol. 102, No. 6, 245-253.

Supovitz, J. A. & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *International Journal of Science Education*, 37 (9) 963 – 980.

Zubrowski, B. (2007). An Observational and Planning Tool for Professional Development in Science Education. *Journal of Science Teacher Education*, 18:861-884.



This document is the result of the common work between the following Fibonacci partners :

Credits

Template design : Brice Goineau

Graphic design : www.lezard-graphique.net

This booklet provides tools to help the effective implementation of an inquiry-based approach to science teaching at school. The tools result from three years of collaborative work among science education researchers, science teacher trainers, and science teachers with different levels of experience in implementing inquiry-based science education in six different European countries. The *Tools for Enhancing Inquiry in Science Education* comprise a *Diagnostic Tool for CPD Providers* and a *Self-Reflection Tool for Teachers*. They were designed to provide teachers and teacher trainers with the means to enhance inquiry in the science classroom, mainly through observation of and reflection on classroom practises. They help teachers and teacher trainers to a better understanding of what is meant by teaching and learning through scientific inquiry, by providing trainers with the means of diagnosing strengths and weaknesses in science teaching practises, and teachers with the means to reflect on their own teaching.

Contact details

Fondation *La main à la pâte*
1 rue Maurice Arnoux
92120 Montrouge - FRANCE
+33 (0) 1 58 07 65 97
Fibonacci@fondation-lamap.org

WWW.FIBONACCI-PROJECT.EU