The Fibonacci Project

DISSEMINATING INQUIRY-BASED SCIENCE AND MATHEMATICS EDUCATION IN EUROPE

Companion Resources For Implementing Inquiry in Science and Mathematics at School

Setting up, Developing and Expanding a Centre for Science and/or Mathematics Education (CSME)

Strategies and lessons from practice

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.

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Preamble

Sustainable Innovation in Education: What Matters and Why?

Louise Hayward and George MacBride, School of Education, University of Glasgow, Scotland

Innovation without change – an expert guide

Over the past decades, given the remarkable number of innovations in education, there has been rather less real change in the experiences of learners than might have been expected. This has been the case even for high-profile and well-funded intentions.

Internationally, we know a great deal about what will not lead to sustainable change. Many of us will have experience of well-intentioned innovations that:

- drowned schools in paperwork in the form of multiple directives, guidelines, reports, forms, ministerial letters;
- set up well-resourced and supported pilot projects which were then 'rolled out' without the resources or support;
- 'cascaded' the innovation: those at the top of the hierarchy understood the innovation and passed its message to others, who passed the message on and, a little like the children's game of Chinese Whispers, by the time the messages reached teachers, they were very different from the original set of ideas;
- measured whatever outcomes were easiest to measure without considering the perverse consequences of this approach.

We know that mechanistic approaches to implementation that do not recognise the importance of the local context when deciding on practice simply do not work (Gardner, Harlen, Hayward & Stobart, 2010)[1]. They may lead to minimalist implementation where superficial evidence is produced for those in authority. Or there may be subversion and distortion of the aims of the innovation. Or there may be serious and damaging unintended consequences.

'Hurricane winds sweep across the sea tossing up twenty foot waves; a fathom below the surface turbulent waters swirl while on the ocean floor there is unruffled calm.' (Cuban, 1994)[2]

Sustainable development in learning

Counter to the failure of such approaches, there is strong evidence that sustainable development in learning takes place when change is seen as inquiry and when policy makers, researchers and practitioners participate and learn together with integrity, recognising their shared goals of improving learning for all (Hayward & Spencer, 2010)[3].

1 Gardner, J., Harlen, W., Hayward, L., Stobart, G. with Montgomery, M., 2010. Developing Teacher Assessments. McGraw-Hill: OU Press.

2 Cuban, L., 1984. How Teachers Taught: constancy and change in American classrooms 1890–1980. New York: Teachers College Press.

3 Hayward, Louise and Spencer, Ernest, 2010. The Complexities of Change: formative assessment in Scotland. Curriculum Journal, 21(2), pp. 161–177.

There are three aspects of integrity in innovation likely to lead to real and sustainable change:

- **Educational integrity:** any innovation must have (and be seen by all involved to have) educational value in that it must be based on recognised and shared principles and be likely to give young people better experiences, leading to better learning and outcomes.
- **Personal and professional integrity:** all those involved must be treated with respect, as subjects who contribute to the planning, implementation and evaluation of the innovation with their views and knowledge recognised and considered.
- **Systemic integrity:** All of the components of the education system must work together to ensure that there is alignment and consistency with the principles of the innovation and avoid unintended consequences.

Thus successful, sustainable change in inquiry-based science and mathematics education will involve starting from where people are: children and young people, practitioners, policy makers, parents and industrialists, in terms of their context, of their thinking, of their strengths and of their areas for development. It requires all involved to recognise that they are learners and members of a learning society.

Effective professional learning in building inquiry-based science and mathematics education is most likely to take place when teachers and others engage in collaborative inquiry, building their expertise, using research and reading as part of reflective practice. Working with colleagues through dialogue and reflection and to analyse and develop professional practice, is an essential part of developing and deepening understanding. To embed inquiry-based science and mathematics education in sustainable ways across a country, will involve the development and support of well-planned partnerships and networks.

Ineffective approaches to innovation share one common feature—change is under-designed (Gardner, Harlen, Hayward & Stobart, 2010)[1]. The idea of how to encourage approaches to change that are sustainable has to be built in from the earliest stages of the process of planning for change.

One group often omitted from plans for educational change are the learners themselves. Yet they are key participants in terms of their rights as recognised both internationally and in the laws of many EU countries. Equally important is that learners have unique insights into their own learning and their perceptions of what matters in their education system. Inquiry-based practice in classrooms is beginning to recognise this especially in terms of learners being engaged in planning for, and reflecting on their own learning. For inquiry-based science and mathematics education to be truly sustainable, perhaps we now need to find ways of engaging learners in planning at all levels of the system.

The CSMEs as a sustainable basis for educational innovations

A Centre for Science and Mathematics Education (CSME) committed to developing inquiry-based learning must model this commitment in its own work. A CSME will be a sustainable base for education innovations in its own context when the three aspects of integrity in innovation are explicitly recognised:

- **Educational integrity:**
  - the first and explicit aim of the Centre is to improve the educational experiences of young people and thereby enhance their learning now and in the future;
  - the development model and practice within the Centre are themselves informed by a commitment to the spirit of inquiry;
  - the experience, knowledge and views of learners contribute to the development of thinking and practice in inquiry-based learning.

- **Personal and professional integrity:**
  - all who will contribute to and benefit from the Centre are involved in the cycle of planning (including questions such as why do this?), implementation and review of its work from the initial stages onwards: teachers, local policy makers and education authorities, researchers, teacher educators (with both beginning and experienced teachers), employers and learners;
  - there is dialogue with all who may see the impact of the Centre about its principles, plans and work: not only members of the above groups but also others, especially parents;
  - no group is privileged within the practice, procedures and structures of the Centre
  - the Centre recognises and builds on the existing knowledge (content and pedagogical), expertise and experience of the teachers and others with whom it works.

- **Systemic integrity:**
  - the Centre promotes institutional and systemic development that supports inquiry-based learning, e.g., where appropriate, policy (local and national), school inspectors;
  - the Centre recognises and seeks to address openly, and with respect, aspects of the education system which may not be consistent with inquiry-based education;
  - learners are involved in planning, implementing and reviewing the work of the Centre and through their participation in research.

Introduction

What is a CSME?

A Centre for Science and/or Mathematics Education (CSME) is an entity in charge of establishing and coordinating a structured and ongoing initiative for taking inquiry-based science and/or mathematics education to the classrooms of the local schools at a city, district, county, or regional level. A CSME can be a university, a teacher-training structure, a school, a science museum, a science academy, or any other institution capable of:

1. providing sustainable and diversified professional development and logistic support to science and/or mathematics teachers at a local level, and,

2. working collaboratively with other local partners of interest (i.e. scientists, municipalities, science museums, etc.).

Pre-requisites for Setting up a CSME

An entity interested in setting up a CSME must necessarily meet the following requirements:

- it must work with schools;
- it must be involved in in-service teacher training or continuing professional development;
- it must have an expertise in inquiry-based science and/or mathematics teaching.

Engaging a large portion of teachers in the initiative is considered here as being a priority. Thus, plans must be made for a preparation phase that may last an entire year. This provides an opportunity to mobilise local actors and partners, and to get them involved in developing the project. More specifically, the viability and success of the initiative will depend upon the following conditions:

- a shared belief in the CSME's long-term challenges and outlooks;
- willingness from political institutions, including vital support from the local and national education system;
- effective mobilisation of local actors (local authorities, scientists, parents, associations, etc.) united around a single project;
- a clear commitment from all partners to allocate the necessary human and financial resources to support each project throughout its life span (at least three years);
- institutional support for the teachers: trust, academic oversight, scientific guidance, training;
- a development plan that combines the CSME's strategic aspects and their subsequent actions, and sets a timetable;
- an official agreement contracting all the partners' commitments for the duration of each project (at least three years).

You may want to assess your entity's potential to respond to these conditions before engaging in the creation of a CSME.

Using this Guide

This booklet comprises two parts.

Part I, "Strategies and Processes for a CSME Initiative", provides an organisational framework for an entity who would like to establish and coordinate an initiative for setting up and developing a CSME. The framework comprises strategies and recommendations as well as lessons for practice in seven strategic work areas.

Part II, "CSME Profiles", includes nine selected profiles from CSMEs that were involved from 2010 to 2013 in the Fibonacci project (www.fibonacci-project.eu). They provide an overview of how the strategies and recommendations described in Part I can be implemented, adapting them to specific cultural, political, and educational contexts. Lessons from practice are also drawn from each of these initiatives. An overview of the specialities of other CSMEs that took part in the Fibonacci project is provided in **Annex 1,** thus giving the reader the opportunity to identify and contact potential collaborators.

This booklet is not intended to be a turnkey template. Although it provides a clear reference framework and a set of functional strategies for developing a CSME, it also intends to leave a considerable space for liberty for **bottom-up initiatives**, capable of responding to specific contextual needs and of making intelligent use of local resources.

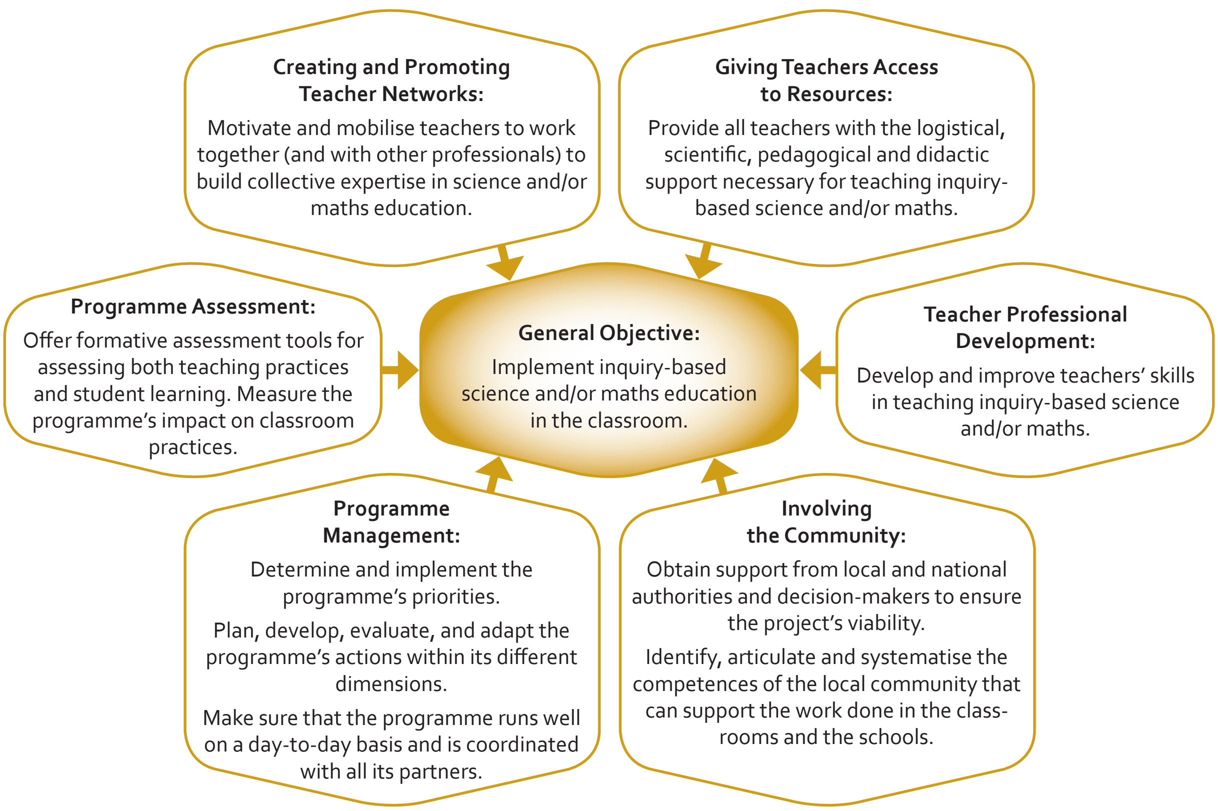
Part I:
Organisational Framework for a CSME

Strategic Work Areas for Developing a CSME

This part of the booklet offers an organisational framework for a CSME, based on seven **strategic work areas**:

- Involving the Community
- Providing Teacher Professional Development
- Creating and Promoting Teacher Networks
- Giving Teachers Access to Resources
- Cooperating with Other CSMEs
- Programme Assessment
- Programme Management

Strategic Work Areas



Each strategic area includes a **main objective** and a list of **specific objectives**. When reading the specific objectives, keep in mind that:

- some specific objectives may be more relevant in some contexts than in others: including them or not within the programme is a decision for each CSME to take according to local needs and to the resources it can mobilise;

- not all the specific objectives can be tackled simultaneously. Each CSME must assess its particular contextual priorities and concentrate on a number of objectives that it can reasonably work on.

For each specific objective, some theoretical background and/or a rationale is provided. In some cases, where it is useful, a list of **key actions** that can be undertaken to reach this specific objective is provided. References to detailed real-life examples of successful initiatives undertaken by members of the Fibonacci Project, described in Part II of this booklet, are provided where relevant.

Finally, for each strategic area, some lessons from practice are provided. They are aimed to prevent actors from making the most current beginner mistakes that others have made before them.

Involving the Community

Main Objectives:

- Obtain support from local and national authorities, from potential funders, and from community representatives to ensure the project's viability.
- Identify, articulate and systematise the competences of the local community that can support the work done in classrooms.

Specific Objectives:

- Raise awareness among key leaders of the importance of setting up or developing a CSME, and of the benefits that the involvement in the programme can bring to their entities.
- Mobilise the leaders into acquiring formal commitments with the programme.
- Promote regularly the actions of the CSME.
- Create original forms of local partnership.
- Give teachers the means to benefit from local partnerships.

An educational initiative such as establishing a CSME is necessarily inscribed in a specific local context (either at a neighbourhood, city, or district level). This context must be carefully examined and associated to the CSME through creative local partnerships. Local partners are crucial because they provide different types of support to the CSME as well as contributing to opening the school to its environment by linking science and mathematics activities with daily life situations and professional contexts[4].

Partners can be academic or municipal authorities, academic or scientific, public or private organisations (universities, museums, research centres or laboratories, enterprises, businesses, industry, associations, cultural centres, etc.), and/or individuals concerned with sciences and/or mathematics (i.e. the pupils' parents).

Raising awareness among key leaders

As soon as the project starts, it is important to identify and inform local organisations that are likely to directly or indirectly contribute to the project. This means analysing each actor's interests and the role they could play in the project, as well as understanding how the project can meet each of their needs and interests. Getting input from such groups early on in the programme will ensure they take ownership of the programme objectives. This is vital in ensuring longer term sustainability of the programme and embedding its actions into the larger education system long after the programme is complete.

4 For a wider discussion on the importance of community involvement, see the presentations made at the Pollen project final conference, New milestones for inquiry-based science education in primary schools in Europe, Panel 2: Community participation and support for dissemination. http://www.pollen-europa.net/?page=8sam2hdh4%2Bw%3D.

Key actions for raising awareness among key leaders:

- Identify the local educational authorities and other entities such as museums, companies, associations, cultural centres, etc., that would be useful to involve in the programme.
- Identify those entities' priorities and interests and specify the role they could play in the programme.
- Contact the leaders of these institutions.
- Raise awareness among these leaders of how useful it would be to create or develop a CSME by:
    - forwarding them a description of the project, presented and argued according to the specific interests of their entity;
    - contacting each leader individually and soliciting their support and commitment.
- Organise a kick-off meeting among all the entities concerned in order to clarify their respective roles and commitments.

Mobilising the leaders

Mobilising the leaders implies creating the spaces necessary to involve them actively in the steering of the CSME initiative, and formalising each entity's commitment to the CSME through signed agreements.

Key actions for mobilising the leaders:

- Identify possible commitments of each of the institutions concerned.
- Involve the leaders in determining the specific objectives of the programme or of a particular project.
- Formalise their commitments to the project through signed, formal agreements that specify the duties of each part.
- Establish decision-making bodies, such as a community board in order to allow an active involvement of each institution in the project's orientations.
- Hold regular institutional meetings

Promoting the actions of the CSME

Promoting the actions of the CSME is crucial for keeping the partner institutions interested and actively involved in the initiative. Since measurable results may take some time to come in on these types of projects, it is crucial to find alternative ways to show the partners that progress is being made and that their efforts are worthwhile.

Key actions for promoting the CSME:

- Develop a brochure describing the programme or a specific project.
- Send regular reports and annual reports concerning the actions of the CSME.
- Send the productions of the CSME to all partners and discuss them at the meetings.
- Invite the leaders into the classrooms where teachers are already implementing an inquiry-based pedagogy.
- Participate at the events organised by the partners.

Creating original forms of local partnership

As soon as a particular project begins, local scientific and cultural organisations should be involved. Partnerships with scientific institutions are highly recommended.

Key actions for creating original forms of local partnership:

- Set up a community board and invite representatives of the interested organisations to inform them and mobilise them around school initiatives.
- Get science and mathematics higher-learning institutions involved in classroom support activities.
- Encourage teachers to organise cultural activities related to the subject being taught in class (for example, plan a visit to a mill during the module on gears).
- Encourage parents to participate in the activities of the CSME and share their know-how.
- Organise actions between partners.
- Promote the programme within the community.
- Organise meetings with local partners to determine the results they expect from the programme.
- Talk to the national science promotional organisation and ask for their support, particularly in promoting the programme and disseminating its findings.
- Even after the programme has started, always keep an eye on new possible partners.

The "TuWaS!" project of the Freie Universität Berlin runs on the basis of an impressive local network involving many different types of partners from the private and public domains who each contribute in a different and creative manner to the success of the project. See the centre profile "Weaving a strong support network to develop and expand a centre for inquiry-based science education" for details → page 41

For more examples of original forms of local partnership with public entities, see the centre profile "A CPD strategy based on in-class support, tutoring, and formal training" from the École de Mines de Nantes. → page 32

Finally, for an example of how community involvement can help to start science centres with very low financial support, see the centre profile "Implementing inquiry-based science education with a low budget and high community involvement", from the University of Belgrade. → page 48

Providing teachers with the means to benefit from local partnerships

Creating local partnerships will not work if teachers are neither informed about them nor provided with the means to benefit from them.

Key actions for providing teachers with the means to benefit from local partnerships:

- Inform schools about the human and material resources made available by local partners that could help them in their science projects.
- Organise targeted meetings between schools and partners.
- Initiate specific projects involving specific schools and partners (i.e., get partners to support teachers in the production of educational resources, get partners to co-organise or co-host public events such as forums, science/math fairs, science/math challenges with schools, etc.).

Lessons from practice

- Wherever possible, involve synergistic organisations and networks who do similar work, so as not to push the programme in as something totally "new", but as something that links in effectively with their infrastructure.
- Make the programme's objectives very clear to the interested parties.
- Make it clear to the community leaders that when implementing educational projects, it may take some time before measurable results are attained. Equip yourself with arguments to convince them that in spite of this delay, their commitment to the project is worthwhile for their entity.
- In order for potential partners to be receptive to requests, the project has to be sufficiently clear and complete. Otherwise, potential partners may not clearly perceive how they can get involved in the project and what role they can assume.
- Quite often, setting up a CSME is an initiative of a small group of people. As the ideas develop, make sure that the potential partners are actively involved in project design. The original group that initiates the proposal should gradually increase in number in order for the programme to have real chances of success.
- Involving the community in the initiative can help to overcome a lack of financial support in the start-up phase.
- Strong support from the Ministry of Education is crucial for a CSME initiative to be sustainable.
- Material and logistic support by local authorities is essential, and it is also a key to sustainability.

Providing Teacher Continuing Professional Development (CPD)

Main Objective:

To develop and improve teachers' skills in teaching inquiry-based science and/or mathematics.

Specific Objectives:

- Diagnose teachers' CPD needs.
- Establish a 3–6 year professional development plan.
- Organise training sessions on inquiry-based science and/or mathematics teaching that respond to teachers' specific training needs.
- Create networks of resource teachers to promote peer support and to facilitate the communication among teachers and the CSME.
- Provide teachers with scientific support from science and/or mathematics students, researchers or engineers.

Teacher Continuing Professional Development (CPD) is a vital tool in changing teaching practices. It is a process consisting of actions allowing in-service teachers to gradually improve and master their teaching[5]. Inquiry-based education, in particular, requires students to become independent learners. In order for this to happen, teachers must develop new relationships with their students and acquire the confidence to allow students to develop their own ideas[6]. Teacher CPD may include several types of activities such as formal training sessions or workshops, coaching from other more experienced teachers or from education researchers, scientific support from science and/or engineering students, co-teaching, or conducting individual or collective action research on

5 Uwamariya, A. and J. Mukamuerera. J.,2005. Le concept de "développement professionnel": approches théoriques. Revue des sciences de l'éducation, 31(1), pp. 135–55.

6 Harlen, W. and J. Allende, eds., 2009. Report of the Working Group on Teacher Professional Development in Pre-secondary School Inquiry-based Science Education. Santiago, Chile: IAP.

their own practice. All of these activities are complementary and must be organised into a coherent, long-term, and progressive CPD plan that takes into account the specific needs of each group of teachers.

Diagnosing teachers' CPD needs

Before designing a CPD programme, it is useful to diagnose the state of science teaching practices 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 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 practices of a particular group of teachers are improving as they acquire inquiry-based teaching experience.

There are several ways to diagnose teachers' CPD needs. One option is to conduct interviews or surveys among the teachers concerned. Even though it is important to take teachers' expectations into account, this may not be enough, particularly if they are completely new to inquiry-based teaching and thus do not have the elements to assess their own teaching in the light of this particular teaching model.

A *Diagnostic Tool for CPD Providers* in inquiry-based science education was developed within the Fibonacci project. The tool is available within the *Fibonacci Companion Resource Booklet* "Tools for Enhancing Inquiry in Science Education"[7].

Establishing a CPD plan

Relating the content of a CPD plan to local and national needs is essential, so taking the time to diagnose those needs, as described in the previous section, is very important. But there are several other important criteria to take into account when designing a CPD plan:

- **Time-related criteria:** several studies indicate that a significant amount of professional development time is needed for teachers to change their teaching practices in a lasting way. Supovitz & Turner[8] found that 80 hours of CPD activities were needed before positive changes could be observed in teaching practices. Changing teaching practices is a slow process, so these 80 hours of CPD should be distributed across a three-year period.
- **Form-related criteria:** both Ratcliffe et al.[9] and Delclaux & Saltiel[10] have attributed the positive impact of a Teacher Professional Development Programme to the inclusion of support provided to teachers inside their classroom within the CPD programme. This does not mean that a CPD programme based exclusively on in-class support is sufficient: a mixture of school-based and centre-based training appears as the most valuable approach.
- **Content-related criteria:** the initial focus of CPD should be on developing science and knowledge skills. It is important to maximise opportunities for teachers to practise new ideas by covering a wide range of topics. Teachers need to be given practical activities that will work with their pupils at the correct level. Persuading them to try the first practical activities in class is essential in triggering pupils' enthusiasm[11].

7 All Fibonacci Resource Booklets are available, free of charge, on the Fibonacci website, within the Resources section.

8 Supovitz, J.A., and Turner, H.M., 2000. The Effects of Professional Development on Science Teaching Practices and Classroom Culture. International Journal of Science Education 37(9), pp. 963–80.

9 Ratcliffe, M., Redmore, C., Aldridge, C., Hurren, C., and Miranda, S., 2010. Impact of Professional Development on a National Scale: The national network of science learning centres. In Contemporary science education research: Pre-service and in-service teacher education, eds. Tasar, M.F., and Çakmakci, G., pp. 295–302. Ankara, Turkey: Pegem Akademi.

10 Delclaux, M. And Saltiel, E., 2011. An Evaluation of Local Teacher Support Strategies for the Implementation of iInquiry-based Science Education in French Primary Schools. Education 3(13)

11 Jarvis, T., Pell A. & Hingley P., 2011 Variations in Primary Teachers' Responses and Development during Three Major Science In-service Programmes. Journal for the Centre for European Policy Studies Vol 1, pp. 67–91.

Checklist for establishing a CPD plan:

- Does the CPD plan last at least three years?
- Does it include at least 80 hours of CPD activities?
- Does it include both in-class support activities and centre-based training?
- Does it include different levels of mastery of inquiry-based science and/or mathematics teaching (beginner to autonomous) and a clear progression from one level to the next?
- Is the CPD plan realistic in terms of available resources and the available pool of trainers?
- Does it rely on teacher networks to support CPD dynamics?
- Does it include an assessment strategy?

A three-year CPD plan can consist of many types of activities. See two very different ways of designing a structured CPD plan according to local needs and available resources and by comparing the following centre profiles:

- "A CPD strategy based on in-class support, tutoring, and formal training" from the École de Mines de Nantes. → page 32
- "Implementing a long-term CPD credited course in inquiry-based science education", from the University of Trnava. → page 35

Nevertheless, in some cases, CPD can also be successfully administered by responding to the punctual needs of the teachers, for example, learning how to use a particular teaching kit. See the following centre profiles for details:

- "Networking among Centres for Educational Resources", from the University College South Denmark, for an example of this form of CPD. → page 38
- "Concepts on resources and materials for secondary schools within a physics museum", from the Université Libre de Bruxelles. → page 45

Organising workshops and training sessions

At the beginning of a project, a training session of two or three days is fundamental in order to provide teachers with the basic knowledge needed to understand what inquiry-based science and/or mathematics teaching is about. It is also important to provide teachers with concrete examples of the benefits of inquiry-based teaching, in order to motivate them to engage and commit to changing their teaching practices.

Later on in the CPD programme, shorter training sessions or workshops on more specific aspects of inquiry-based teaching, or on particular science or mathematics content that teachers are having trouble with, may be organised.

For examples of possible contents of the training sessions within a structured CPD plan, see the following CSME profiles:

- "A CPD strategy based on in-class support, tutoring, and formal training" from the École de Mines de Nantes. → page 32
- "Implementing a long-term CPD credited course in inquiry-based science education", from the University of Trnava. → page 35

Providing scientific support to teachers

One of the most recurrent obstacles to teaching inquiry-based science in primary schools, where teachers are most often generalists who have to teach all subjects to their students, is a teacher's weaker knowledge of science. Research has shown that primary school teachers are considerably less confident about their knowledge in science than about their knowledge of other curricular subjects such as reading and mathematics[12].

Providing teachers with scientific support from science students, science researchers, or engineers, can be a good way to support teachers in becoming more familiar with scientific content and overcoming their apprehensions about teaching science[13]. This form of teacher support is effective, provided that it is carefully planned and coordinated by the CSME. Students and scientists themselves must be trained before going into the classrooms. A training session, regrouping the supporting students/scientists and teachers who will receive their support, is essential. Such a workshop is the opportunity to make clear the role of the supporter in the classroom. However, the supporter must never replace the teacher, who will continue to conduct his/her sessions normally. The supporter is there to help the teacher to understand better the scientific contents he/she will work on with the students and to help him/her to make authentic scientific inquiry happen in the classroom. During the workshop, each teacher and his/her supporter can work out the best way to work together according to the teacher's particular needs and the supporter's availability.

For an example of how scientific support can be planned and organised, and for a detailed description of the roles of the supporter, see the CSME profile "A CPD strategy based on in-class support, tutoring, and formal training" from the École de Mines de Nantes. → page 32

Providing support from resource teachers

Peer-to-peer collaboration is a very effective support for teachers, particularly during their second year of training, when the basic principles of inquiry-based teaching have already been acquired and teachers start implementing them in the classroom. Peer collaboration helps teachers find solutions to the problems they encounter when implementing inquiry-based teaching. It helps to improve active collaboration among teachers, promotes communication between schools, and it favours the expansion of the project.

In order to provide peer support to teachers new to inquiry-based teaching, some CSMEs have successfully established networks of resource teachers. Resource teachers are experienced teachers who give pedagogical advice and support to less experienced teachers concerning inquiry-based teaching in their schools. They receive more hours of training in inquiry-based teaching than the other teachers. Their main roles are the following:

- use the CSME's pedagogical resources in their classroom and introduce them to other teachers;
- help the CSME to develop and improve pedagogical resources;
- help other teachers in planning their science/math sessions and provide them with in-class support when necessary (for example, during science sessions in which experiments will be conducted);
- help the CSME to identify their colleagues' specific training needs;
- make sure that the teachers use the materials available in school for teaching science and/or mathematics, and all the necessary materials for teaching inquiry-based science and/or mathematics are available in the school grounds and up-to-date.

12 Harlen, W., 2008. Science as a Key Component of the Primary Curriculum: a rationale with policy implications. Perspectives on Education 1 (Primary Science), pp. 4-18. {Online}. Available from: www.wellcome.ac.uk/perspectives. {Accessed: October 5th, 2008}.

13 Hvass, M.,Jasmin, D., Lagües, M.,Laporte, G., Mouahid, G., and Saltiel, E., eds., 2007. Supporting Teachers through the Involvement of Scientists in Primary Education. Pollen Project. {Online}. Available from: http://www.pollen-europa.net/?page=24gl%2FNYrAeE%3D. {Accessed: October 1st, 2012}.

Key actions for providing support from resource teachers:

- Identify the teachers who wish to become resource teachers.
- Organise a specific training session for your resource teachers.
- Assign a resource teacher to each individual beginner teacher.
- Create a working group of resource teachers on the adoption and implementation of pedagogical resources.
- Organise regular meetings among resource teachers in order to report on their actions, on their colleagues' training needs, and discuss possible courses of action.
- Regularly train resource teachers in the use of new resources, so that they can present them to their colleagues.
- Involve resource teachers in the development of new resources.

Lessons from practice

- When diagnosing teachers' CPD needs, it is important that teachers understand that their teaching practices are not being evaluated and that the diagnostic will not have an effect on their teaching careers.
- In some countries, because of the characteristics of the school system, teachers are not used to having visitors and thus will not easily open up their classrooms for diagnosis nor for CPD actions. In such situations, the diagnostic phase may be a good time to persuade teachers of the benefits of opening up their classrooms.
- Scheduling time for training over several years is an important component of a project's success. It is important to ensure that teachers' superiors provide teachers with the necessary time and space to attend the sessions.
- Scheduling training sessions outside of teachers' regular working hours may discourage them to attend.
- If training takes place during school hours, the school must help the teachers to find replacements for their classes.
- Scientific support does not replace training, it only complements it.
- Support from science or engineering students works better when the support counts as a formal part of the students' university course and thus is closely supervised by a university professor. Formal agreements with universities and/or colleges are thus strongly recommended.
- Iterative cycles of class experience and pedagogical debriefing brings teachers to self-efficiency.
- Teachers' self-confidence, as a key to their motivation, can be enhanced through on the field support during a limited time, with a decreasing supporting input thereafter.
- A resource teacher should never take the lead during the science lessons, nor act as a specialist. This hinders the development of the teacher's autonomy and may produce uneasiness. The resource teacher is there to support the teachers, not to replace them.
- Support by resource teachers does not replace formal training, but rather complements it.
- Raising teachers' self-confidence is a key factor in improving their capabilities in inquiry-based teaching.
- Helping teachers to self analyse their own practice is a powerful lever in improving inquiry-based learning.
- Inquiry-based teaching requires intensive and long-term preparation of teachers, because their concept of teaching must be redesigned.
- Analysing the lessons in one particular class is a very effective training strategy, keeping in mind that every group of children is different and needs different guidance, instruction and help.

- It is important to support each individual teacher in the process of developing an inquiry-based approach to their own teaching.
- The development of units based on pilot studies in schools has a strong transmissibility both for teachers and for trainers.
- There needs to be a balance between action and reflection (goal-directed planning and evaluation) and autonomy and networking (analysis of own situation, support by experienced colleagues at school or trainers) in order to set up a sustainable support system for schools.
- CPD programme development requires continuous feedback to evolve in the right direction.

Creating and Promoting Teacher Networks

Main Objective:

Motivate and mobilise teachers to work together (and with other professionals) and to build collective expertise in science education.

Specific Objectives:

- Promote formative co-assessment of teaching practices.
- Promote collective theme-based projects.
- Create and promote teacher discussion groups.
- Involve teachers in the collective production of educational resources.

A qualitative change in teaching practices requires time and depends largely on group effort. A teacher's mid and long-term willingness and capacity for conscious engagement in transforming their teaching, is a key factor to ensure sustainable change[14]. Support, exchange, and co-assessment systems enable teachers to share and compare their practice, their thoughts, and their individual skills, and thus to consciously engage with others in the transformation of their teaching. And, most importantly, it enables teachers to remain the primary drivers of their own careers.

A very efficient model of large-scale teacher networking, which inspired the networking model of the Fibonacci project, was developed within the German SINUS project. The model is described within the centre profile "Teacher networks as a success factor within a large scale project", from the University of Bayreuth.
→ page 51

Promoting co-teaching and formative co-assessment of teaching practices

Encouraging teachers to teach in pairs, to prepare their lessons together, and/or to assist each others' lessons as observers is a good way to enhance a fruitful dialogue. Encourage them to make descriptions and analyses of each others' teaching practices and to produce reports for their trainers, or to discuss them within teacher discussion groups. Recording discussions between pupils and analysing them, in order to assess their comprehension of the concepts being worked on, is another interesting activity to do in pairs.

The section "Assessing student learning" on page 25 of this document contains some useful strategies and references to tools designed to promote formative co-assessment among teachers.

14 Gather Thurler M. and Bronckart, J.P., 2004. Transformer l'école. Brussels: De Boeck.

Promoting collective projects among teachers

Proposing pedagogical, theme-based projects for teachers to do with their students is a great way to stimulate teacher networking. Making such a project work implies developing teaching resources that all teachers involved in the project can use, and training the teachers to use them. Teachers can of course be involved in the whole process. Be sure to build the project around a subject of real interest both to teachers and to students and that which enables the study of a significant amount of scientific and/or mathematical concepts.

Other forms of collective projects among classes, such as science forums which expose children's work, or school newspapers, articles, or blogs, are good ways of getting teachers to work together in exchanging experiences and know-how.

Greenwave is a pedagogical, theme-based project that brings teachers and classrooms from all around Europe together. The Serbian science centre participated actively in this project. See the centre profile "Implementing inquiry-based science education with low budget and high community involvement", from the University of Belgrade, for details. → page 48

Creating and promoting teacher discussion groups

Teacher discussion groups can be very efficient learning networks. These can be organised between primary and secondary teachers from the same school, or among teachers from different schools.

Various activities can be planned within the discussion groups. Plan some time for preparing teaching sequences and analysing classroom practices (see section on co-teaching and co-assessment). From time to time, consider inviting other professionals, such as psychologists or teacher trainers, to join teachers in this activity.

Inviting scientists and/or mathematicians to the discussion groups will allow teachers to deepen the study of specific themes of interest. Also consider inviting other professionals who are capable of enriching knowledge on particular subjects (businessmen, artisans, associations, museums, labs, etc.).

Teacher discussion groups can also help identify teachers' needs in terms of pedagogical resources (sequences on particular subjects of local interest, tools for assessing both student and teacher learning, etc.). Be sure to recognise, share, and promote the work of these groups.

Involving teachers in the collective production of educational resources

Set up resource production groups (adoption and use, or adaptation and improvement of modules and sequences).

Developing pedagogical resources involves a great deal of testing inside the classroom. You can involve teachers in testing these resources in their classrooms with their students.

Danish teachers share their teaching units through a web-page. See the centre profile "Networking among Centres for Educational Resources", from the University College South Denmark, for details. → page 38

Lessons from practice

- It is important to recognise the work done by teachers within teacher networks as an integral part of the time devoted to professional development. Official recognition of the value of this time spent with peers is essential to keep up teachers' motivation and to ensure the success of teacher networks.
- Creating a community of practice makes the inquiry-based approach easier to implement.
- Working in a community of practice strongly improves the whole efficiency of the CPD process.

- Participating in open class visits creates natural cooperation among in-service teachers.
- Common goals including freedom for individual adaptations lead to high acceptance of proposals for change.
- Teachers should be respected as experts of teaching and learning.
- Good practice cannot be cloned, but exchange of experiences on a personal level supports learning and innovation.
- Teacher networks offer goal-oriented exchange processes among teachers, which supports professional development of teachers (i.e. fresh ideas for classroom teaching, inter-disciplinary cooperation in schools).
- Teacher networks can create a culture of trust, raise self-esteem, encourage teachers to take risks, and upgrade inquiry-based teaching at school.

Giving Teachers Access to Resources

Main Objective:

Provide all teachers with the logistical support and with the resources necessary for teaching inquiry-based science and/or mathematics.

Specific Objectives:

- Diagnose the needs for resources and establish a loan system.
- Monitor the use of resources.
- Diversify, actualise, and improve the resources.

Changing a teaching strategy implies changing and adapting the resources previously used in the classroom. Inquiry-based teaching requires children to become independent learners. Thus, they will be required to:

- do a great deal of hands-on activities: this implies having enough materials available in the classroom for each child or each small group of children to carry out experiments or make observations on the particular subject that will be studied;
- do a good deal of bibliographical research: this implies children having access to books or magazines on the subjects taught.

Teachers, on the other hand, will also need teaching guides and modules that propose activities especially conceived for inquiry-based teaching.

Giving teachers easy access to the resources necessary for inquiry-based teaching is fundamental (although not wholly sufficient) for inquiry to happen in the classrooms. Without the resources, setting up an inquiry-based activity becomes so burdensome for teachers that discouragement is very likely to follow. Giving teachers access to these resources requires substantial planning and monitoring from the CSME.

Some projects, such as *La main à la pâte* in France, have developed a great deal of inquiry-based science teaching resources which are free of translation fees, provided an agreement is signed with the project. In Serbia, a science centre was started with practically no financial support thanks to this possibility. See the centre profile "Implementing inquiry-based science education with low budget and high community involvement", from the University of Belgrade, for details of how this might be done. → page 48

Other projects, such as SINUS, have translated a selection of their resources to English and made them available for free on the Internet. See the centre profile "Teacher networks as a success factor within a large scale project", from the University of Bayreuth, for details. → page 51

Diagnosing the needs for resources

In order to decide what resources to buy, adapt, or develop, the CSME must take several factors into account: what resources are already available for teachers to use, both inside and outside the school? Can these materials be adapted for inquiry-based teaching? What are the teachers' wishes in terms of subjects to be studied? A careful diagnosis is required.

Key actions for diagnosing the needs for resources:

- Make an inventory of the resources already available in each school, in the district area, and at the CSME.
- Identify teachers' needs and wishes for resources (materials and modules).
- Build with the teachers a programme of subjects to be studied during the school year and identify the resources needed to teach these subjects. If you are starting from zero, consider planning resources for only 2 or 3 subjects.

The Belgium science centre has found that the needs for resources in primary schools are very different from the needs for resources in secondary schools and thus have developed resources adapted to the latter. See the centre profile "Concepts on resources and materials for secondary schools within a physics museum", from the Université Libre de Bruxelles. → page 45

Establishing a loan system

Once the first resources are acquired by the CSME, a loan system must be set up and teachers must be informed of its existence. An interesting option for organising the loan of teaching resources is organising them inside boxes containing the teaching module, as well as all the materials needed for teaching that particular subject.

In order to choose the subjects for which teaching kits will be elaborated, create a study schedule for every academic year. When scheduling, keep in mind the following points:

- the themes chosen should refer to the regional and national curricula;
- every year is composed of periods of about seven weeks between each school holiday; this provides an opportunity to identify major scientific and/or mathematics themes per year throughout the pupils' education.

Involving the teachers and the academic coordinators in the process of choosing the subjects for which the teaching kits will be elaborated is crucial.

Key actions for establishing a loan system:

- Produce a complete list of resources available either for borrowing or for on-site consultation (at the CSME, in other entities at the district level, and within each school).
- Establish a loan system with clear rules and produce a document describing them.
- Make the list of available resources and the document describing the terms of the loan system available to the teachers.

Monitoring the use of resources

To fully optimise loaning of the kits to schools, a rotation schedule can be established and sent to teachers at the beginning of each school-year. The schedule indicates the period at which every subject can be tackled, and specifies the dates during which materials can be borrowed and returned.

In order to help you keep track of refurbishing needs, consider including a tracking sheet within each teaching kit that teachers can use at the end of every period to mark materials that are missing. Estimate the annual refurbishing budget for the kits at about 10% of the total cost of the materials.

The tracking sheet may also be used by the teachers to write their comments concerning the use of the materials. This will help the CSME to improve the contents of the kits. Also consider asking the schools for feedback on their experiences with the logistics of resource loaning.

Lessons from practice

- It is essential to involve the teachers in elaborating the programmes of the subjects to be studied and in choosing the modules and the materials that will be used.
- When fabricating teaching kits, it is important to anticipate and plan for the time needed to put them together. It is difficult to gauge how much time is required because it may vary considerably from kit to kit, according to the subject of the module.
- Cost can be lowered considerably by encouraging teachers to use low-cost materials that are easily available to children at school and at home. Work with teachers to adapt them to their particular needs.
- Primary and secondary schools need different tools for implementing inquiry-based teaching because their time and task management is completely different.
- Units and didactic materials have to match the local curriculum.
- Familiar and ready to use equipment encourages teachers to take a first step.

Cooperating with Other CSMEs[15]

Main Objective:

To cooperate with other CSMEs in order to learn from them and to disseminate the actions of the CSME.

Specific Objectives:

- Establishing twinning partners.
- Visiting the partner on the field.

Learning from others is a fundamental component in the development of a CSME.

"Twinning" is a form of close cooperation between an experienced CSME and a CSME with little experience. This cooperation may involve trying out different approaches to teaching and to training together, training teachers together, building common teacher networks and learning communities, doing research together, developing assessment tools and methods, or even exchanging ideas on how to introduce inquiry-based approaches in pre-service teacher education.

Twinning has clear benefits both for the more experienced and the less experienced CSME. On the one hand, for the less experienced CSME, twinning can lead to an acceleration of the process of acquiring expertise in all the strategic work areas, as well as gaining access to recent research on inquiry-based teaching and learning. The more experienced CSME, on the other hand, learns how to better promote and implement inquiry-based education and to disseminate the outcomes of what it has already accomplished. Twinning is a win-win situation for both centres.

15 This section is based on the results of the external evaluation of the Fibonacci Project, carried out by Magda Kirsch and Yves Beernaert of Educonsult.

Establishing twinning partnerships

Twinning can be a very efficient and effective strategy provided that it is built on structured cooperation over a time period of approximately two years, and that some basic rules are observed which structure this cooperation.

In the preliminary phase, before making the cooperation official, the following factors are crucial:

- Similar visions on mathematics and/or science education in general and on inquiry-based science education or inquiry-based mathematics education in particular are key factors of constructive and synergetic cooperation. Thus, an exchange on the visions between the two partners is essential.
- Defining and analysing the strengths and needs of each partner is fundamental, because it sets both the terms and foundations for a successful cooperation. A field visit to each centre is an interesting source of information for achieving this diagnosis together.
- The terms of the cooperation should be formally expressed in a document which clarifies the responsibilities and the duties of each centre, describes the activities to be carried out (field visits, workshops, support in setting a community board, exchange of tools or pedagogical material, etc.), sets clear deadlines, and provides financial information.

The costs of the cooperation between the two centres should be very clear from the beginning and both centres must make sure that all the activities planned are funded. On-going formative evaluation during the period of cooperation, as well as summative evaluation at the end, are key elements in efficient and effective cooperation. Regular communication between the centres is crucial.

Disseminating the results of the cooperation contributes greatly to evaluating what has been achieved. Thus the outcomes will also be beneficial for other organisations. Local, regional and national authorities should be informed that twinning can contribute to policy making and possibly to enhancing the mainstreaming of inquiry-based science and mathematics education in many more schools.

The TuWaS! project of the Freie Universität Berlin is an inspiring example of the multiple benefits of twinning, both for the experienced and the less experienced partner. See the centre profile "Weaving a strong support network to develop and expand a centre for inquiry-based science education" for details. → page 41

Annex 1 provides a list of potential twinning partners and their specialities. → page 62

Visiting the partner on the field

Field visits are an excellent way to find out whether or not collaboration between two CSMEs could be beneficial. They can also be the first step in a cooperation that has already been made official. The advantage of a field visit is that several members of one CSME can jointly visit the other CSME. This stimulates cross-fertilisation and networking. Provided that they are well planned and organised, field visits can turn out to be real peer learning activities.

The programme of a field visit should be the result of joint reflection and preparation of the guests and the hosts. A three-day field visit by a beginner CSME to an experienced CSME could include the following elements:

- a thorough briefing on what inquiry-based science and/or mathematics education stands for;
- visits to classrooms to show inquiry-based teaching is being implemented;
- attending a training session given to teachers in the framework of CPD, and possibly a session of a course for future teachers in the framework of pre-service teacher education;
- visitors should have the opportunity to discuss and reflect with teachers, principals, pupils, future teachers and their educators after attending a lesson or a training session;

- meetings with the community board members and other key stakeholders supporting the CSME initiative, with a focus on sustainability and mainstreaming;
- a presentation of the work done by the visiting CSME;
- a discussion on how the cooperation between the two CSMEs could be organised and on the terms of this cooperation;
- a short evaluation session with regard to the benefits of a possible cooperation between the CSMEs.

If the CSMEs are in two different countries, then before the field visit all visitors should be given background information on the community board, the country's educational system, and the state of inquiry-based science and/or mathematics education. Also, before the visit, the visiting CSME should inform its host of the actions that it has already undertaken and of the areas in which it wants to improve, so that its host can address these specific issues during the field visit.

When organising a field visit, it is crucial to have a good balance between theory, practice, reflection, and in-depth exchanges between all the participants. Hands-on activities are particularly important because they allow the participants to experience what inquiry-based learning is all about, thus providing a solid ground for reflection and theorisation.

Programme Assessment

Main Objective:

Measure the programme's impact on classroom practices by assessing processes, teaching practices, and student learning.

Specific Objectives:

- Doing both formative and summative assessment.
- Assessing the programme's processes.
- Assessing teaching practices.
- Assessing student learning.

Programme assessment is a process that involves collecting data in a systematic way, interpreting it as evidence of how well a set of objectives has been reached, and using that information to help further progress. Planning any sort of assessment implies strictly defining the following four aspects[16]:

- A conceptual framework: what exactly is to be evaluated (i.e., a particular process, inquiry-based teaching, inquiry-based learning, a particular form of knowledge, a particular skill)?
- The objectives to be evaluated: what exactly does optimal performance look like in this particular case?
- A selection of data sources (i.e. an activity, a set of questions, the pupils' notebooks, an observation, etc.) and a set of tools to organise the data (i.e. charts, forms).
- A set of criteria for interpreting the results of the evaluation (i.e. defining the levels of performance) in order to draw conclusions from it (i.e. identifying what needs to be improved).

16 Shavelson, R., Ruiz-Primo, M.A., Li, M., and Cuauhtemoc, C., 2003. Evaluating New Approaches to Assessing Learning. National Centre for Research on Evaluation, Standard and Student Testing. Los Angeles: California University. See also NRC, 2001. Knowing What Students Know: the science and design of educational assessment. Washington D.C.: NAP.

In setting up and developing a CSME, assessment is crucial because it helps to improve its organisation, its work with teachers, and teachers' work with pupils. At least three dimensions of the work of a CSME must be assessed:

- the process put into place to reach an objective;
- the actual changes in the teaching practices;
- student learning.

Assessing each of these different dimensions pertains to different assessment methods, objectives, and tools. Nevertheless, before proceeding in measuring the programme's impact on pupils' learning, it is crucial to determine whether or not the implementation of the programme complies with the model. In other words, student learning must be assessed only after having assessed the programme's processes and the teaching practices. Only after it becomes apparent that inquiry-based learning has been an integral part of the pupils' practice for a sufficient amount of time can you assess the outcome of what they have learned. Otherwise, you run the risk of drawing the wrong empirical conclusions, which can lead to faulty decision-making[17].

Moreover, two types of assessment—formative and summative—should be considered for each of these dimensions. The main difference among these two types of assessment is their purpose: formative assessment implies using the evidence collected in order to obtain information about the process in question and improve it; summative assessment, on the other hand, implies using the evidence collected in order to measure the results obtained during a particular process and report on it to individuals or groups for accountability. There is no method of assessment that is inherently "formative" or "summative".

Assessing Continuing Professional Development actions

Assessing CPD actions is most efficiently done by observing teaching practices in the classroom, in order to identify the aspects of inquiry-based learning that are being implemented well, and those where attention is needed. For this purpose, an observation grid with a set of indicators for judging on the implementation of inquiry-based learning is necessary.

The *Diagnostic Tool for CPD Providers*, developed by a group of Fibonacci partners, was designed to assess CPD actions. The tool is available within the *Fibonacci Companion Resource Booklet* "Tools for Enhancing Inquiry in Science Education"[18].

Formative assessment of teaching practices

Stimulating reflection on the teaching and learning that has taken place in a particular session raises awareness of relevant aspects of pupils' work that may otherwise go unnoticed and not given the attention they deserve. However, it is important to help teachers identify the aspects of teaching and learning which are relevant to reflect on, particularly when they are new to inquiry-based teaching. A special tool was designed for this purpose within the Fibonacci project (see the example box). Keeping a portfolio throughout the project is another way of encouraging teachers to continually reflect on their teaching[19].

17 IAP, 2006. Report of the Working Group on International Collaboration in the Evaluation of Inquiry-based Science Education (IBSE) programs. Santiago, Chile: Fundación para Estudios Biomédicos Avanzados. {Online}. Available from: http://www.ianas.org/meetings_education/me {Accessed: October 1st, 2012}. eting55.html. {Accessed: October 1st, 2012}.

18 All Fibonacci Resource Booklets are available, free of charge, on the Fibonacci website, within the Resources section.

19 For ideas of how this might be done, see Harland, T., 2005. Developing a Portfolio to Promote Authentic Enquiry in Teacher Education. Teaching in Higher Education, Vol. 10(3), pp. 327–337.

A *Self-Reflection Tool for Teachers*, which provides a list of criteria expressed as questions that teachers can ask themselves about a sequence of science activities which were intended to enable pupils to learn through inquiry, was designed by partners of the Fibonacci project. The tool is available within the *Fibonacci Companion Resource Booklet* "Tools for Enhancing Inquiry in Science Education".[20]

Assessing student learning[21]

Formative assessment of student learning

Formative assessment is integral to inquiry-based teaching and learning. Using formative assessment ensures that students have the kinds of opportunities needed for real understanding.

Teachers using formative assessment:

- are clear about the goals of their work and the criteria of quality to be used in judging where pupils are in relation to the goals;
- communicate these goals and criteria effectively to pupils;
- observe and question pupils and use their reports and artefacts to gather information about on-going learning;
- interpret this information, identify progress and the next steps;
- give feedback to pupils and use it to adjust teaching;
- involve pupils in self and peer-assessment.

Formative assessment of student learning requires a clear definition of the teaching objectives ultimately being sought in terms of knowledge and skills. Consequently, it is of the utmost importance to help teachers determine and adopt these objectives.

Summative assessment of student learning

What is assessed and reported in summative assessment of student learning influences what is valued and given priority in teaching. For this reason, it is very important that summative assessment of student learning reflect the full range of goals of inquiry-based learning in science and/or mathematics.

The data for assessing student learning can be collected in several manners, for example:

- through tests, which can be either designed by the teacher, or externally designed, either internally or externally marked;
- through a summary of observations concerning the pupils, made by the teacher and judged by the teacher;
- through judgement of portfolio work selected by the teacher and/or the pupil;
- through embedded tasks observed and marked by the teacher;
- or through a combination of these.

The way in which the assessment information is collected influences what is assessed and reported. In order to assess inquiry skills, it is important to create contexts that engage students' thinking and in which they are observing, raising questions, collecting, analysing and interpreting data, drawing conclusions, and communicating their findings.

Traditional tests are not particularly adapted for assessing inquiry skills. Assessment by teachers on the basis of the activities that the students do in class, on the contrary, can be much better adapted to the full range of goals that characterise inquiry-based teaching. Other advantages of teacher assessment is that it can relieve the pressure, on pupils and teachers, of terminal tests and examinations, and that it can release resources (time and

20 All Fibonacci Resource Booklets are available, free of charge, on the Fibonacci website, within the Resources section.

21 This section draws largely from Harlen, W., 2012. Student Assessment and Inquiry-based Science Education: issues in Policy and Practice (in press).

other costs) for alternative use. Moreover, teachers can use the information they collect about their students' learning both for formative and summative purposes.

Nevertheless, teacher assessment also presents some disadvantages that must be compensated by training and preparation—teachers' judgements are not always reliable. Making reliable judgements implies having a provision of detailed, progressive criteria, and being agile in recognizing when these criteria are being met in practice by the students. Some suggestions for increasing the reliability of assessment by teachers are presented in the "Key actions" box.

Key actions for assessing student learning:

- Encourage assessment by teachers on the basis of activities that students do in class, over traditional testing.
- Organise seminars and discussion groups on assessment of inquiry-based teaching.
- Work closely with the teachers in order to increase the reliability of their assessment, by:
    - helping them determine a set of moderation procedures;
    - providing teachers with, or helping them to build, a set of detailed, progressive criteria;
    - exemplifying judgement-making on each particular criteria by presenting teachers with concrete examples taken from practice with children;
    - organising group discussions of assessed work among teachers;
    - organising standardised tasks or short tests in order for teachers to cross-check their judgements.

The University of Ljubljana in Slovenia, has largely reflected on the assessment of student learning in inquiry-based science education. It has developed tools for this purpose, and it has conducted evaluations which have produced interesting conclusions. See the centre profile "Needs of teachers are central, but evaluation and assessment are equally important" for details. →page 57.

Lessons from practice

- Evaluation of teaching practice in direct link with the curriculum has a large influence on teaching.
- Teachers are at the heart of a reform, but teaching is only the beginning. Evaluation and assessment of pupils' learning are equally important. Providing teachers with tools for evaluation and assessment on the progress of their pupils is crucial for the success of implementing inquiry-based education.
- Summative assessment of pupils' learning determines teaching.
- Evaluation and research needs to be orientated towards an iterative connection between an interest to gain new knowledge and a developmental interest. A culture of self-critical and collective reflection might flourish, but reflection should not hamper the project's implementation.

Managing the CSME

Main Objectives:

- Determine and implement the CSME's priorities.
- Plan, develop, evaluate, and adapt the CSME's actions within its different dimensions.
- Make sure that the CSME runs well on a day-to-day basis and is coordinated with all its partners.

Planning

Planning aims at anticipating the various actions and resources necessary to implement the initiatives of the CSME, and at organizing them through time. Planning is essential to starting the initiative, and requires a detailed and sometimes long preparation, including both reflection and contact-making. It should result in a comprehensive and concrete document describing the operational aspects of the project. This document can then be the basis of a future partnership agreement.

Key actions concerning programme planning:

- Define the frame of the programme and its main goals.
- Establish the limits of the area of action of the CSME.
- Establish how the programme will be implemented.
- With the programme's goals in mind, draft a three-year strategic development plan.
- Determine a list of actions for the different phases of development of the programme.
- Plan for a location to store the resources and to train the teacher trainers.
- Establish a provisional budget (number of positions, operating costs, spending for materials, travelling, etc.)
- Produce a document containing a global description of the programme, that can be sent to potential partners and schools.
- Present the programme to decision-makers in order to ensure their support.
- Present the programme to potential funders.
- Present the programme to other institutions and/or individuals that may be interested in getting involved.
- Present the programme to schools and take close note of their reactions.
- On the basis of these discussions, progressively build up a collective agreement among all partners liable to get involved in the programme.
- Sign partnership agreements with a three-year action plan.

Steering the CSME

Steering the CSME or, in other words, setting its course or determining its priorities, is the task of the steering committee.

The steering committee should include representatives from the institutions that the CSME has signed formal agreements with. It has decision-making power and controls the projects' set-up. It monitors and steers the projects. Its decisions concern subjects such as the number of classes that will be involved in a particular project, the geographic areas that will be covered by the project and the budget, etc.

A detailed example of the setup, the functions and the operation of a steering committee for a regional network, and of the national coordination of these committees, is provided by the IMST project in the centre profile "Operating and evaluating regional networks, a project initiated by the government", from the Alpen-Adria Universität Klagenfurt. → page 54.

Day-to-day coordination

The day-to-day coordination of a project is the task of a coordination team that may include:

- a general coordinator, who is the main contact for all the partners, schools, and teachers involved in the project;
- a training coordinator, preferably a trainer from the national education administration, whose primary role is to train the teachers and monitor the classes participating in the project;
- a resources coordinator, in charge of diagnosing the teachers' needs for resources and attending those needs, and eventually organising the development of new resources;
- an assessment coordinator, in charge of formative and summative programme assessment.

Lessons from practice

- In nationwide projects it is important to create a sense of ownership from all participants and to align expectations. This could by establishing suitable channels and tools of communication.
- When setting up a centre, learning from the experience of partner projects is very important because it speeds up the initiative's implementation and growth. But it is advisable to adapt to local needs, which might differ from those of experienced partners.
- Responding to the needs of teachers and schools is important, otherwise it will be difficult to recruit the teachers.
- CSMEs often grow faster than expected. Thus, looking for partners to support work in the classroom and ensuring financial support from the very beginning of the initiative, is crucial.
- A small, enthusiastic group of teachers and trainers capable of giving a strong impulse to inquiry-based teaching is crucial at the beginning of a project.
- Successful and sustainable changes need long-term projects, a crucial number of participants and high recognition and assistance from the responsible institutions.

Part II: Profiles of Centres for Science and/or Mathematics Education

Overview of CSME Profiles

Each CSME is unique. It has used specific strategies to adapt the organisational framework described in the first part of this booklet to its country's curriculum, school system, economic strengths, and to the specific needs of local teachers and schools. The accounts of the paths that each CSME has followed, the difficulties it has encountered, and the solution it has given to its problems, offer an abundance of experiences from which others can profit.

In this second part of the booklet we present nine profiles of CSMEs that were involved in the Fibonacci project. They give an overview of the diversity of strategies that can be implemented in the development and expansion of a CSME. Each team presents the history of its initiative inscribed in local settings and shares experiences and lessons learnt in the process. The CSMEs were selected in order to convey the existing diversity with respect to the teaching subjects addressed, to the organisational framework of the centre, and to the focus on specific strategic work areas. The profiles are thus an inspiring and lively mirror of CSMEs throughout Europe.

A short overview of the specialities of other CSMEs, all of which took part in the Fibonacci project, is presented in **Annex 1**. It provides a pool of potential partners for collaboration.

Overview of CSME profiles presented in the following sections

→ see following double page

CSME	Speciality	page
École des Mines de Nantes France	**A CPD strategy based on in-class support, tutoring, and formal training** **Target group:** primary and middle school (from kindergarten to grade 9) **Subject focus:** science **School education system:** national **Networking/Community involvement:** university, informal science laboratory/learning facilities such as science centres, sciences forums, private schools **Financial support:** governmental **Materials:** made by the centre, lent to supported teachers **CPD:** in-service training courses, tutoring, networking and hands-on accompaniment **Curriculum relevance:** Material adapted to the National Curriculum **Evaluation:** Feedback by the teachers and tutors, school visits, follow-up questionnaires	32
Trnava University Slovakia	**Implementing a long-term CPD credited course in inquiry-based science education** **Target group:** kindergarten, primary and lower secondary school (age 6 - 14) **Subject focus:** science **School education system:** national **Networking/Community involvement:** district and regional network **Financial support:** governmental **Material:** starting package of inquiry-based science activities with materials; biology, biochemistry, chemistry and physics for over 30 lessons **CPD:** 110 hour credited CPD course **Curriculum relevance:** we aim to integrate inquiry-based science education within the curricula **Evaluation:** feedback from the teachers, school visits	35
University College South Denmark	**Networking among Centres for Educational Resources** **Target group:** primary school (grades 1 to 6) **Subject focus:** science **School education system:** federal **Networking/Community involvement:** informal science laboratory, university, foundation, companies, Berlin–Brandenburg Academy of Sciences and Humanities **Financial support:** governmental, foundation, companies, European Union, fees **Material:** commercial with a teacher's guide being lent to schools for 5 months for a fee **CPD:** obligatory one day training on each of the topics **Curriculum relevance:** material adapted to the Berlin curriculum **Evaluation:** questionnaires and feedback by the teachers, school visits, Pollen evaluation	38
Freie Universität Berlin Germany	**Weaving a strong support network to develop and expand a centre for inquiry-based science education** **Target group:** primary school (grades 1 to 6) **Subject focus:** science **School education system:** federal **Networking/Community involvement:** informal science laboratory, university, foundation, companies, Berlin–Brandenburg Academy of Sciences and Humanities **Financial support:** governmental, foundation, companies, European Union, fees **Material:** commercial with a teacher's guide being lent to schools for 5 months for a fee **CPD:** obligatory one day training on each of the topics **Curriculum relevance:** material adapted to the Berlin curriculum **Evaluation:** questionnaires and feedback by the teachers, school visits, Pollen evaluation	41
Experimentarium, Université Libre de Bruxelles, Belgium	**Concepts on resources and materials for secondary schools within a physics museum** **Target group:** pupils/students from 5 to 18 years old **Subject focus:** science (focus on physics/environmental science), mathematics **School education system:** federal, each community organises its own education system. **Networking/Community involvement:** University of Brussels, Board of Education, Brussels Regional Council, research centres, private companies, Physics and Chemistry Teachers Association, Royal Academy of Sciences, Brussels Region, Brussels Environmental Agency (IBGE), pedagogical advisors, inspection, teachers **Financial support:** European Union, Brussels Region, University of Brussels **Material:** developed or adapted for inquiry-based science and mathematics education by the Experimentarium **CPD:** training sessions organised for primary, secondary teachers and also for future teachers. **Curriculum relevance:** All material fit the curriculum (we are also involved in the design of the new curriculum) **Evaluation:** questionnaires, participation and feedback from the teachers after training	45

CSME	Speciality	page
VINCA Institute – University of Belgrade Serbia	**Implementing inquiry-based science education with low budget and high community involvement** **Target group:** pre-school, primary and secondary school teachers **Subject focus:** science, cross disciplinary **School education system:** central **Networking/Community involvement:** with other projects on inquiry-based science and mathematics education, teachers, platforms, university, companies (school publishing house), Academy of Sciences and Arts, Serbian Physics Society, Serbian Ministry of Education **Financial support:** free of charge publication of translated books, Fibonacci project **Material:** translated books, experimental kits developed by ourselves **CPD:** 8 hours training per teacher on different topics **Curriculum relevance:** Ministry of Education introduced optional subject called "Hands-on-Discovery of the world" in 2003 **Evaluation:** planned (questionnaires for and feedback by teachers, school visits, Fibonacci evaluation)	48
University of Bayreuth Germany	**Teacher networks as a success factor within in a large scale project** **Target group:** teachers (grade 5-12), teacher students, teacher educators **Subject focus:** mathematics, science, technology **School system:** federal **Networking:** regional networks in all 16 German Laender (federal states); teacher networks supervised by moderators **Financial support:** Ministries of Education, companies and other sponsors, European Union **Materials:** regular textbooks, database www.sinus-transfer.de (background papers, material for teacher training, worksheets and lesson units), special booklets written by teachers for teachers, **Professional development:** in-house and regional training courses, special seminars for trainers and moderators **Community involvement:** Ministry of Education, Regional Educational Administration, teacher associations, parents, museums, special initiatives by companies **Curriculum relevance:** National Educational Standards based on the ideas/outcomes of SINUS **Evaluation:** self-evaluation by teachers, external evaluation by questionnaires and portfolios	51
Alpen-Adria Universität Klagenfurt, Austria	**Operating and evaluating regional networks, a project initiated by the government** **Target group:** teachers from K – 12, as well as teacher educators **Subject focus:** science, mathematics, technology, German **School system:** federal system in Austria **Networking/Community involvement:** regional networks in all nine Austrian provinces, some district networks and Regional Educational Competence Centres (RECC) **Financial support:** governmental, companies, European Union **Materials:** reports by teachers about teaching and learning (including learning materials) **Professional development:** seminars, courses, facilitation and networking **Curriculum relevance:** support of concrete practice projects of teachers **Evaluation:** self-evaluation by teachers and networks and external evaluation/concomitant research (questionnaires, interviews)	54
University of Ljubljana Slovenia	**The needs of teachers are central, but evaluation and assessment are equally important** **Target group:** kindergarten and primary school (grades K to 5) **Subject focus:** science **School education system:** central **Networking/Community involvement:** University of Ljubljana, Board of Education, primary schools, city councils, general public, parents **Financial support:** European Union, small companies, city councils **Material:** developed at the Faculty of Education, lent to teachers for a week without a fee **Professional development:** obligatory one afternoon training on each of the topics (minimum 3 topics per year) **Curriculum relevance:** all materials comply with Slovenian curriculum **Evaluation:** questionnaires and feedback by the teachers, school visits, pupils' assessment, Pollen and Fibonacci evaluation	57

A CPD Strategy Based on In-class Support, Tutoring, and Formal Training

Michaël Canu, Lotfi Lakehal-Ayat, Nathalie Michel, Carl Rauch, École des Mines de Nantes, France

The beginning: promoting inquiry-based science education in primary schools by providing resources and hands-on support

The initiative of the École des Mines de Nantes (EMN) started in 1996, when Physics Nobel Prize winner Georges Charpak launched the French project *La main à la pâte* with the support of the French Ministry of Education. In the Nantes area, 35 teachers were chosen in order to develop resources for teaching science through inquiry. A local steering group was created with science education professors, local representatives of the Ministry of Education (inspectors and pedagogical trainers), and scientists from EMN. During the first years of the project, 20 teaching kits in science and technology (S&T), each including a scientific protocol and all the necessary experimental material, were built. The kits covered topics like air, electricity, light, water cycle, waste recycling, states of water, power, germs and time measurement, etc. Teachers were supported by EMN science students when they used the kits.

Growing up: community involvement and specialisation in CPD

This local initiative grew considerably during the following years through the inclusion of new partners:

- The City of Nantes, through its Science Resource Centre.
- A Science Pilot Centre, created in 2007 and affiliated to *La main à la pâte*.
- The Science Faculty of the University of Nantes.

Each of these partners made a commitment to contribute to the initiative in its own way: the University of Nantes hires students for in-class support, and the Science Resource Centre lends equipment and rooms. In 2002, the French Ministry of Education, inspired by the success of *La main à la pâte*, introduced inquiry into the national science curriculum for primary schools, and a few years later for middle schools. This decision led us to change the organisation of the Nantes science centre and to broaden its goals. Focus was put on developing a CPD strategy that would allow teachers to master inquiry-based teaching and to become self-sufficient in implementing it. In 2010, our involvement in the Fibonacci project was a good opportunity to improve this strategy.

A strategy for teacher CPD

The CPD strategy is planned over a period of three years. This period of time allows the development of a community of learning. Communication among teachers and exchange of practices take place during training sessions by working on the same topics, and during the year through the use of a website. Working together, sharing resources and experiences, in turn creates a community of practice in inquiry-based science education.

The CSME of Nantes provides CPD to at least 40 teachers every year (including 20 new ones each year). Thanks to the optimisation of the organisation, the activities' area was expanded.

We can now organise training sessions simultaneously in different parts of the Nantes region (e.g. in Nantes and another town located 50 km away), as well as do a follow-up of the teachers *on the field*. The Fibonacci project led the partners to structure their collaboration more deeply—combining resources and efforts and sharing know-how and tasks. Moreover, discovering CPD in other Fibonacci centres was of great help in questioning our own strategy.

Our CPD strategy comprises 3 poles:
1) In service training: Teachers attend either two (for private schools) or three (for public schools) in-service training sessions during their first year of training, and one session during the second year. During the first training session (1 day in October), they experience real inquiry through an adult-suited topic, but as if they were

students. This experience allows us to introduce the main features of inquiry-based education. Then they work in small groups on ready-to-use teaching units for the class.

The second training session (in December) aims at analysing the teaching units just tested, in order to identify in retrospect the main steps of inquiry and the difficulties encountered. Examples of written records from the pupils are used. Finally, the teachers prepare new teaching units for the following period on the basis of less detailed documents that lead them to a more individual reflection.

During the third training session (held in April-May), the teachers are required to give more and more personal input. They are asked to prepare the following year's programme with new teaching units and to define the skills to be developed. They are also asked to identify the parts of the teaching units that they feel able to manage without in-class support (see below under 2).

The fourth training session (in October, second year of the project) focuses on assessment of pupils' skills. Only at this step of the CPD process, thanks to the field experience they have acquired, teachers have become able to face this fundamental issue which requires a comprehensive understanding of the relation between inquiry and learning.

2) In-class scientific support is proposed to teachers at a rate of one lesson per week. Each teacher gets support for 12 weeks during the first year of training and for 6 weeks during the second year. The French Ministry of Education gave the support in science and technology for the primary school official through a national charter in 2004. This is the legal frame within which almost all the activities of our centre take place. Concretely, the volunteer engineering students, PhD students and scientists involved in providing scientific support help teachers to:

- prepare inquiry-based science activities and resources;
- carry out activities in the classroom (debate, inquire, experiment);
- analyse and debrief what happened during each lesson, in order to understand which components of scientific inquiry were well implemented and which have to be improved.

The supporting scientist should never assume the responsibility of the class, but should only make things easier for the teacher. Thus, his/her task is compared to that of a piano accompanist with a singer. Both "accompanist" and teacher have to build an efficient duo, which is quite a difficult task. That is why they are tutored by a senior scientist *and* teacher.

3) Tutoring: Tutors are senior teachers at university level and/or teacher trainers. four of every five tutors are also engineers or physicists working in science research departments. They are in charge of coordinating the training sessions and the scientific support, and of assisting the teachers and the science students that accompany them. Some teachers and most students feel quite uncomfortable at the beginning. That is why the tutor has to attend some lessons in the classroom in order to advise both of them, and to share experience with the accompanist. Moreover during the third year, as teachers have to implement inquiry-based teaching alone in their classrooms, the fact that the tutor keeps in touch with them may be of the highest importance to keep them motivated.

First outcomes and assessment of the CPD process

The fundamental issue for primary school teachers is that they often start almost from scratch in S&T. Instead of bridging the wide gap, their in-service training time will rather be optimised by training them through inquiry about research and learning methodology. In this manner, they may become skilled in self-learning and acquire the knowledge they need in the future by themselves.

Even motivated beginner teachers often feel they will not be *able to apply* inquiry-based teaching. The only way to *convince* them that they are really capable is to support them *on the field* before, during and after a certain number of lessons (we suppose, about 20). Thanks to the combined support of trainers, tutors and accompanists, teachers will firstly experience some short positive teaching situations and then to integrate some fragmented skills through a structured post-analysis. Sharing good and bad experiences with other teachers prevents them from feeling like "the only one who fails" during this discovery step.

It turns out that the first year of our CPD is in fact similar to basic elements of inquiry-based learning. Figure 1 compares both CPD content (in-service training + accompaniment + tutoring) with main elements of inquiry-based methodology:

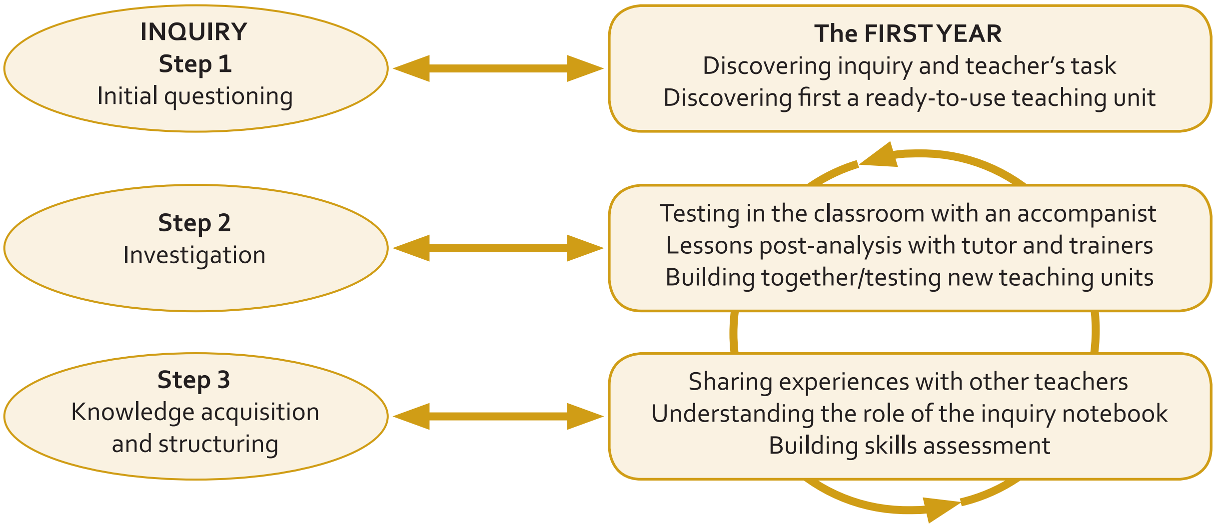


FIGURE 1: COMPARISON OF CPD CONTENTS WITH MAIN ELEMENTS OF INQUIRY-BASED METHODOLOGY

As steps 2 and 3 are iterative (3 cycles during the 2 first years), teachers progressively go into inquiry-based teaching in greater depth and start developing self-confidence (figure 2).

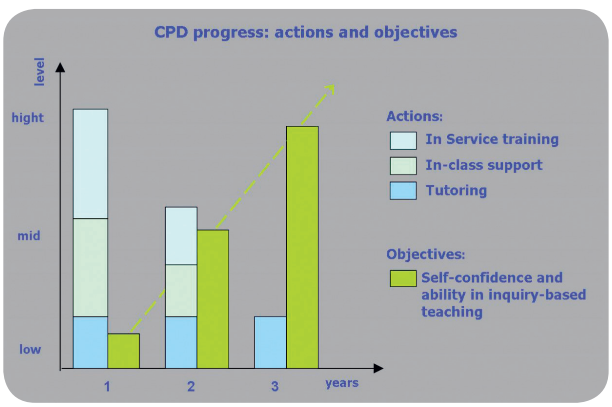


FIGURE 2: IMPACT OF CPD ON THE TEACHERS´ SKILLS AND SELF CONFIDENCE

Sharing practice and skills with other teachers working on the same topics is far more effective than speeches from trainers and tutors. This staff role is to give tools and methods. With this aim in view, trainers and scientists permanently assist the teachers' teams in analysing experiences, building new teaching units and standing back from the everyday activity. Working in such a community of practice, and sharing know-how between primary school teachers and university S&T teachers is for both sides a highly fruitful, as well as, a win-win strategy—the former feel comfortable with children's cognitive and social developments, while the latter frequently use S&T concepts and teach transversal competencies.

So far, we have not assessed systematically the implementation of inquiry in classrooms. Nevertheless, we are starting a reliable process. Testimonies show that the teachers appreciate working with resource people who do not belong to schools a lot. They also highly appreciate the classroom accompaniment. The next step will be to see whether they continue inquiry-based education beyond their CPD time.

Lessons learnt:

- Teachers' self-confidence, as a key to their motivation, can be enhanced through *on the field support* during a limited time, with a decreasing supporting input thereafter.
- Working in a *community of practice* strongly improves the whole efficiency of the CPD process.
- Iterative cycles of *class experience* and *pedagogical debriefing* bring teachers to self-efficiency.

Implementing a Long-term CPD Credited Course in Inquiry-based Science Education

Katarina Kotulakova, University of Trnava, Slovakia

Trnava University: a theoretically and practically prepared science centre

The team at Trnava University Science Centre comprises lecturers at the Faculty of Education from the chemistry, biology, pre-primary and primary education departments. We have a long-term history in elaborating a constructivist approach in science education, which is the theoretical background of inquiry-based learning. Since our institution prepares future teachers, these ideas are incorporated into their pre-service training programme. Some of our educators were involved in the implementation of the constructivist orientated programmes in the 1990s in lower secondary education through the FAST project (Foundational Approaches to Science Teaching),[22] as well as in applying an inquiry-based approach to science teaching in primary education through the project *La main à la pate*[23].

The Slovak pedagogical environment is very conservative, and financial support from the government is low; there is no positive climate for reform in education. The contents that students have to learn are very dense and high standards have to be met. Teachers complain about having too little time for such a load and about not having satisfactory teaching material.

Despite all these problems, we were convinced that testing the programme FAST project in Slovakia would be very positive. FAST prepares teachers to teach science concepts with an inquiry-based approach and helps to develop teachers' content knowledge of physical, biological and earth science. FAST emphasises the need to increase students' ability to communicate what they are learning through oral reports, project work, graphing, flow charts, and diagramming. FAST also helps students to develop thinking skills, laboratory skills, and to increase their knowledge of the foundational concepts.

Agreement between European support and inner tension in education

An accumulation of problems with the national curriculum resulted in an educational reform in 2008. This reform gave teachers more freedom in relation to teaching content and strengthened the goal-orientation of education in order to gain certain competencies. But most importantly, it introduced Continuing Professional Development (CPD) programmes for teachers. The CPD was linked to economic stimulus for the teacher. Through this, teachers also had further motivation to attend training sessions in innovative approaches to teaching. At that time, we were invited to join the Fibonacci project. Thanks to the previous experience, the team at Trnava University, had quite a clear idea of how we wanted to implement inquiry-based teaching and learning in science education.

Continuing Professional Development (CPD) and support

When we joined the Fibonacci project, a period of very intensive teacher training started. We designed a credited course of 110 lessons. In the preparation phase, we directly contacted regional authorities and headmasters of schools to promote and "advertise" the approach of our CPD training courses. A set of activities with methodological guides for kindergarten, primary and lower secondary was elaborated and used as training material. The Fibonacci project gave us a platform to finance the courses and to provide basic material for teachers participating in the course. The theoretical background of the programme illustrates the development of science education and how the approaches to science education have changed in the country. It stresses the importance of pupils' prior knowledge (pre-conceptions and mis-conceptions) and presents the principles of inquiry-based science education. In the practical part, the focus lies on improving the skills that teachers need

22 For an overview of the FAST project, see http://www.hawaii.edu/crdg/sections/science/documents/fasteval.pdf.

23 For an overview of the La main à la pâte project, see www.fondation-lamap.org.

for implementing inquiry-based science teaching: creating stimulating situations, improving their questioning skills, handling and searching for suitable equipment and tools. Additionally, teachers prepare guiding material for pupils (worksheets), and they experience inquiry by registering, analysing, and evaluating data, and finally drawing conclusions.

The following is a list of the titles of the different sessions that make up our CPD training course:

- Inquiry-based science education – theoretical introduction and main principles.
- Introduction to working with pupils' preconceptions in science.
- Development of key competences through the implementation of inquiry-based science education.
- "Science" as school subject within the school educational curriculum.
- Inquiry-based learning in practice and theory in more detail.
- Scientific communication. Oral and written forms of research reports and their significance for science and for science education.
- Conceptual changes in understanding of main targets of elementary science education in traditional instruction and inquiry-based instruction.
- Meaningful use of different kinds of tools, aids and materials to support inquiry-based science activities.
- Field work: Get to know different methods of data collection and materials
- Learning through trial and error and experimenting as two different practical activities—working with hypothesis and predictions
- Short introduction on how to assess the development of science skills.
- Pupils' science notebook as a simple model of research report and its educational significance.
- How to use worksheets to support the pupils' inquiry process.
- Graphs, diagrams, tables – how to use them to develop scientific thinking.
- Using different kinds of secondary information sources.
- Involvement of the scientific community.

The special design of our long-term course gave us the opportunity to meet teachers not only in our spaces and in our labs, but to visit them in their classrooms and analyse the lessons they teach to their own students. Participants on our course are also invited to observe their colleagues' open lessons. An essential part of those open lessons is the follow-up discussion.

At the beginning, in the first lessons of the course, the teachers are asked to use science inquiry activities designed by the teacher trainers. Our team members developed over 30 lessons on topics of biology, biochemistry, chemistry and physics for training purposes for ISCED 0, 1 and 2 (kindergarten, primary and lower secondary level). Teachers receive the material for the activities on the topics they are trained on. The topics are later taught in in-service teachers' classes. The trainers accompany the teachers' activities and give them feedback. In a latter stage of the course, having acquired more experience and interiorised the principles of inquiry-based science education, the teachers are asked to develop their own activities.

In our experience it is very effective to analyse the lessons in one particular class, knowing that every group of children is different and needs different guidance, instruction, and help.

Opportunities for teacher networks

We train around 80 teachers per year from the western part of Slovakia (Trnava area). The intensive courses, including the open class visits, create a good opportunity to build a vital network among teachers and trainers, as well as for the teachers among themselves. This partnership is profitable for all sides. Especially in the open classes they learn to analyse, get feedback, justify steps they have taken, get inspired, gain confidence etc. The meetings at the teachers' home schools offer the possibility to react and solve one's needs and exchange ideas in given school conditions. Many of the participating teachers let our pre-service teachers visit their lessons and even help us to guide them. Teachers see inquiry-based teaching as being very demanding but at the same time very meaningful.

Community involvement

In order to support the introduction of inquiry-based science teaching and learning into formal education, the local Fibonacci team encouraged particular local authorities to join the local community board. Up to now the community board consists of eight members: the rector of Trnava University in Trnava, teacher trainers, a member of the Slovak Academy of Science, school founders, a member of the Methodological Centre for Pedagogy. Based on our experience, we can say that mainly school founders helped us with practical implementation into formal education, as they could directly reach the school directors and support teachers' interests for innovation in science education innovation.

Assessment

The assessment of the CPD courses is done at several levels. In order to reach a specific level of excellence, we perform multiple observations. Each teacher makes a final presentation of his/her work at the end of the in-service training. Teachers are asked to prepare their own inquiry-based activities, which are evaluated according to the basic principles of inquiry-based science education. Only the teachers who are well familiarised with inquiry-based science education obtain a certificate of excellence.

Additionally, the external evaluators of the Fibonacci project (EDUCONSULT) give feedback, especially to coordinators and trainers. We are also working on assessment of student learning. During regular meetings with teachers, we discuss how to assess student learning in the classrooms. We are presently developing an assessment tool for this purpose. In our opinion, assessment is very important in promoting inquiry-based science education in the academic community.

Future

Today, there are several academic institutions in Slovakia participating in European projects with a focus on inquiry-based science education. This promises a constructive dialogue on implementing an inquiry-based approach to science teaching in Slovakia. To promote the implementation of inquiry-based science education and strengthen our science centre, we continuously cooperate with educational authorities and we develop additional material for schools.

Lessons learnt:

- Implementing inquiry-based science education in an unprepared educational system is not an easy task.
- Inquiry-based science teaching requires an intensive and long-term preparation of teachers: teachers' concept of teaching has to be redesigned.
- For training purposes, it is very effective to analyse the lessons in one particular class knowing that every group of children is different and needs a different guidance, instruction and help.
- Participating in open class visits creates very natural cooperation among in-service teachers which is profitable for all sides.

Networking among Centres for Educational Resources

Ida Guldager, University College South Denmark

The beginning: giving teachers access to resources from the 1930s onwards

The Centres for Educational Resources were founded in their early form in the 1930s as "school centrals" – places where teachers could get information on the available school books. During the following decades, the number of school centrals reached more than 20 and the services expanded to providing teacher's guides and the lending out of material, as well as pedagogical guidance and trips to educational fairs. In the early 1970s legislation was made regarding the services of the centres. An update of the legislation later brought the centres to their current status, in which a network of Regional University Colleges encompasses the sub network of Centres for Educational Resources. These act as resource and development centres for schools and other educational institutions rectified by the same national legislation, which reads as follows:

Figure 3: Material store in Aabenraa. © University College South Denmark

"Article 2,1. The function of the Centre for Educational Resources is:

- to build up a collection of teaching resources intended to be on loan to educational institutions;
- to provide information and offer guidance to teachers regarding the teaching resources in our collection and their use;
- to support teachers in developing their personal teaching resources."[24]

The centres now host a complete collection of up-to-date school handbooks and related material covering the educational needs of the schools and institutions we serve. Furthermore, the collection includes a large selection of audiovisual learning materials and multimedia resources. The schools served by the centres have weekly deliveries of materials, which have been booked through the online platform or the phone.

Strength of the Danish model for organising material support and CPD courses

- By having a copy of all available teaching books, the Centres for Educational Resources offer a huge variety to the teachers, and not only books from a specific publisher.
- The national network offers great possibilities for knowledge sharing and joint development of educational materials.
- Material boxes developed at a certain Centre for Educational Resources can very quickly be distributed to all centres, and distribution will be followed by nationwide teacher training on that specific subject.
- The national network ensures a certain buying power towards the companies who deliver educational materials, giving the best value-for-money.
- The new "Centres for Educational Resource – national standards" will ensure a uniform offer to all schools in Denmark.
- As the Centres focus on all subjects, the cross-curriculum activities are heavily supported by the pedagogical advisors and CPD is offered.
- The Centres are updated on IT-based teaching and develop common educational platforms.
- The Centres all use the same booking system, making it easy to support each other.

24 Translated from The Danish Legislation. 2012. Consolidation Act No. 1306 of 11th of December 2006, with the changes imposed by § 73 of Act No. 562 of 6th of June 2007. {Online}. Available from: https://www.retsinformation.dk.{Accessed: 15th March 2012}

However, in periods of recession we meet the following challenges:

- The national funding also makes the centres visible and vulnerable to national cutbacks in times of economic difficulties.
- The booking system is the same at all Centres for Educational Resources, however it is not possible to book materials at another Centre.
- Making joint CPD courses without developing a form of internal competition in order to secure the revenues from the training.

CPD: encouraging the development of a school-based approach in inquiry-based teaching

In Denmark it has been a tradition to focus on the students' ability to phrase questions by focusing on phenomena in the surroundings that caught the students' attention and using the students' questions and investigations as the basis. The teachers will see this attention as a key concept for understanding a child's quest to discover and learn.[25]

In our in-service education we have a focus on the inquiry-based approach to teaching, since the teachers are already skilled in mathematics and science. The pedagogical advisors from the Centres for Educational Resources organise CPD workshops alternating between periods of tutoring, and experiences are shared permanently on the national webpage. Teachers are encouraged to design their own approach to their teaching by developing their own units. These are shared on the webpage. Each school has its own portfolio page.[26]

In order to develop a common understanding of inquiry-based science and/or mathematics education, the University College South Denmark and The National Organization of Centres for Educational Resources in Denmark decided to take part in the Fibonacci project.

FIGURE 4: COLLECTION OF MATERIAL, © UNIVERSITY COLLEGE SOUTH DENMARK

Curriculum relevance

In the Danish National curriculum, the 'working methods and ways of thinking' in science and mathematics are described as competences that the students should acquire. The following passages are from the curriculum for 2nd and 3rd grade.

Science: "Phrasing questions and hypotheses based on observations, investigations, etc."
"Completing and describing small scale investigations and experiments"
"Comparing results and data for both practical and theoretical studies using drawings, diagrams, tables, digital images […] and communicating them"

Mathematics: "Working experimentally and in an investigative way involving concrete materials"
"Working individually and cooperatively solving practical problems and mathematical tasks"
"Engaging in dialogue about mathematics, where students' different ideas are involved"

25 Leicht-Madsen, Bent, 1984: Se her! Forlaget Børn og Unge, København.

26 Here are some examples of teaching units developed and shared by teachers: Building Bridges: http://www.fibonacci-project.dk/deltagende-skoler/gredstedbro-skole-gredstedbro; Mathematics in Balls http://www.fibonacci-project.dk/deltagende-skoler/ankermedets-skole-skagen; and Spiders http://www.fibonacci-project.dk/deltagende-skoler/risingskolen-odense

This legislation supports the development of an inquiry-based approach to teaching. But it also has given us the challenge that some teachers find the inquiry-based approach to teaching to be 'old wine in new bottles'.

A nationwide project: a challenge for networking

As we started the Fibonacci project, we soon found that the most important task was to ensure that everyone had ownership of the Fibonacci project. All pedagogical advisors from the Centres for Educational Resources that took part in the project met for common workshops before the projects at the schools started. These workshops created a mutual understanding of an inquiry-based approach to science and mathematics teaching, which could then be disseminated in the Fibonacci schools. As the Danish project is nationwide with the partners placed all over Denmark (figure 5), daily "corridor-talks" are impossible, making it so much more important to align the expectations. We try to accomplish this by sharing experiences and ideas on our webpage, as well as the portfolio pages of the schools and by arranging regional kick-off conferences with workshops and the presentation of ideas by the more experienced teachers, and finally by publishing newsletters every other month. Furthermore, the nationwide approach has made it easy to spread out and test the material in different areas of the country, giving us feedback from several users in a very short period of time.

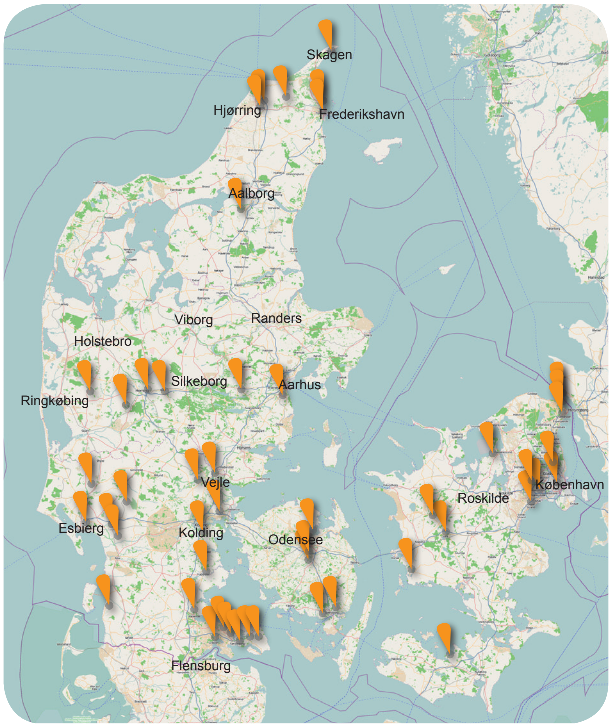


FIGURE 5: PARTNERS OF THE DANISH PROJECT
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In the Danish project we focused on using the existing materials and adapting them to an inquiry-based approach, as the centres have a huge compilation of material boxes for science and maths. We also developed some units for use in collaboration with our twinning partners in Spain and Portugal, as they do not have the same material compilations as we do in Denmark. These units have now been used for in-service training in Denmark, Germany, Spain and Portugal, sharing the concept of an inquiry-based approach to science and mathematics teaching.

Lessons learnt:

- The importance of supporting the individual teacher in the process of developing an inquiry-based approach to their own teaching.
- The development of units based on pilot studies in schools has a strong transmissibility for both teachers and trainers.
- In nationwide projects, it is important to create a sense of ownership of the project from all participants and to align expectations. This could be achieved by establishing suitable channels and tools of communication.

Weaving a Strong Support Network to Develop and Expand a Centre for Inquiry-based Science Education

Petra Skiebe-Corrette, Freie Universität Berlin, Germany

The beginning: responding to the needs of teachers and schools

In 2005, the Berlin school system added the new subject "science" in grades 5 and 6 and increased the number of topics concerning science and technology in grades 1 to 4. These changes were difficult for the schools to implement. The majority of primary school teachers did not study science and were (and still are) afraid to teach it. Also, most schools do not have special rooms to teach science and lack the materials for hands-on science activities. The time was ripe for a programme that would support those teachers to teach the new curriculum.

When I was introduced to the NTA programme (Science and Technology for All, Naturve Tenskapoch Teknik för Alla)[27], I realised that such a programme could help Berlin teachers. In the process of finding funding for such a programme, the Freie Universität Berlin was invited by *La main à la pâte*[28] to join the European project SciencEduc[29] as an associate partner.

We also take part in *Pollen*[30], the follow-up EU programme. The aim of Pollen was to support inquiry-based science education in 10 primary schools in each of the 12 participating countries, each country developing its own strategy to reach that goal. Since the need of interested schools was high, and to sustain the project beyond *Pollen*, TuWaS! – Technik und Naturwissenschaften an Schulen (Technology and Science in Schools)[31] was founded by the Freie Universität Berlin and the Berlin–Brandenburg Academy of Sciences and Humanities. "TuWaS!" translates to "DoSomething".

Learn from others and share: teaching material and professional development

In order to be implemented as quickly as possible, TuWaS! adopted many characteristics of the Swedish NTA programme. Thus, we chose not to develop our own teaching materials but to use already existing commercial teaching materials that were developed by the National Science Resources Center (NSRC). A number of reasons supported this decision. Most of the 24 topics available suited the German curriculum. It was pedagogically appropriate and allowed to build up conceptual understanding over several lessons. The material focuses on inquiry, was field-tested in the USA and had been implemented in Sweden. Each unit includes enough experimental material (consumables and non-consumables) to allow 30 children to experiment for up to 3 months, and a guide for the teacher. With help from Sweden, the Freie Universität Berlin received a contract that allowed TuWaS! to translate the teaching material and adapt it to German schools. This adaptation process was performed by teams that included both primary teachers and scientists. So far, we have adapted 10 topics (weather, solids & liquids, life cycle of butterflies, plant growth and development, electrical circuits, chemical tests, motion & design, microworld, food chemistry and ecosystems). Like the NTA program, TuWaS! established a material centre that rents the teaching materials to schools for five- month periods.

In order to efficiently implement a professional development programme, TuWaS! invited trainers from Sweden and from the NSRC to run workshops in Berlin. Now TuWaS! offers day-long workshops for each of the 10 topics. **The workshops are run in the best case by two people, one being a primary teacher the other being a scientist.** The teachers perform the same experiments as their pupils will do later in school. After attending the workshop, they can rent the material for a fee. It includes everything that is necessary for the planned experiment or lesson, thus freeing up the teacher for the teaching and not needing to spend precious time shopping for the material themselves.

27 Further details can be found on http://www.nta.kva.se/In-English/

28 Further details can be found on http://www.fondation-lamap.org/en

29 Further details can be found on http://www.scienceduc.cienciaviva.pt/home/

30 Further details can be found on http://www.pollen-europa.net/

31 Further details can be found on http://www.tuwas.fu-berlin.de/

In addition to the topic workshops, TuWaS! is developing workshops that focus more on topics such as "how to use a notebook" or "how to combine science lessons with improving language literacy". Here we learned from our Fibonacci partner, Luxemburg, and from other programmes such as *AMSTI* (Alabama Math Science and Technology Initiative)[32].

Think big and look for partners: community involvement

When TuWaS! started in Berlin, our Swedish mentors told us to think big, because the programme might grow faster than expected. This was a warning; we did not pay enough attention to this, but we soon realised that we should have done.

An idea which we did take very seriously from the *Pollen* project was to involve the whole community (figure 6). In order to spread the cost of the programme, TuWaS! tried to diversify its supporters. This is important for several reasons. If there is only one main supporter, the programme is extremely dependent and if this one supporter is lost, the programme collapses. Also, different supporters bring different types of skills, knowledge and support for the programme. Support does not always mean money.

The co-founder of TuWaS!, the Brandenburg Academy of Sciences and Humanities, provides knowledge and the support of renowned scientists, as well as a political connection. The academy also hosted two conferences on inquiry-based science education. Early on, TuWaS! was also supported by the TSB Technologiestiftung Berlin, which funded teaching material for technology topics and provided the salary for the head of the material centre. In addition, the TSB Technologiestiftung Berlin helps to promote TuWaS!.

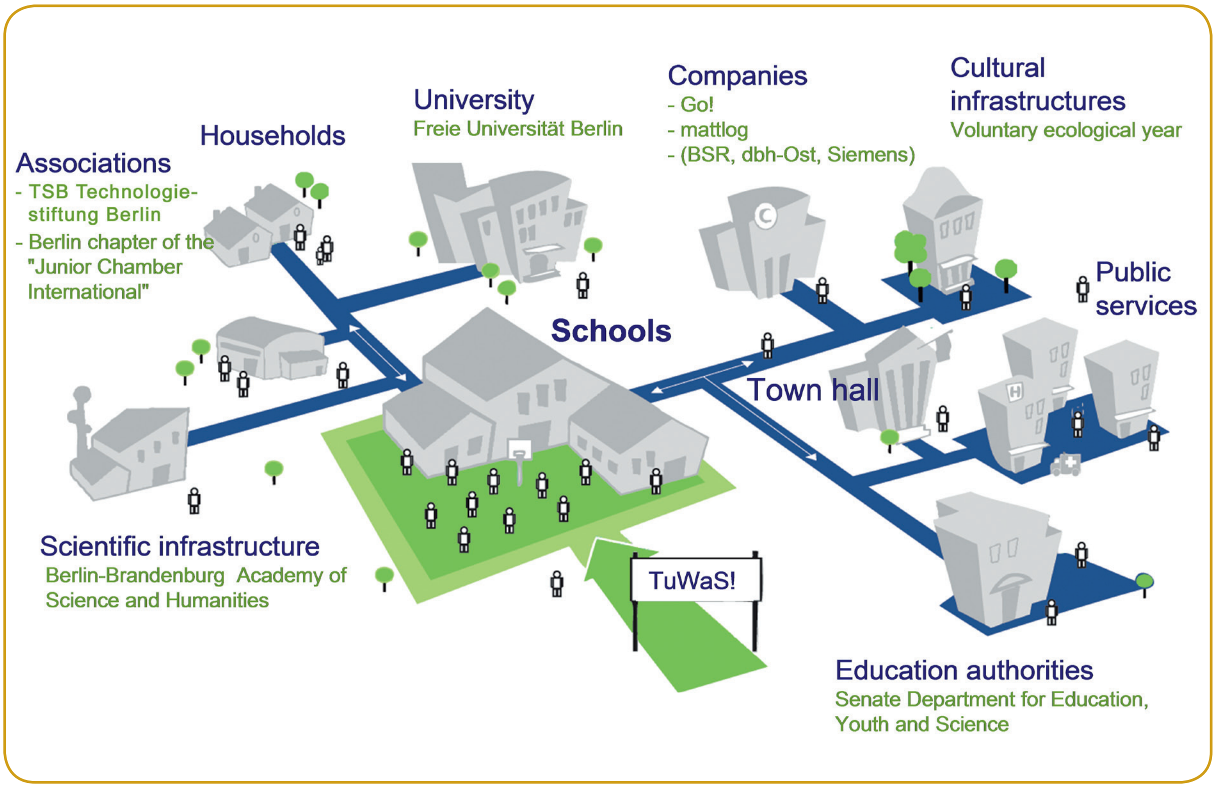

FIGURE 6: TUWAS! IS SUPPORTED BY NUMEROUS STAKEHOLDERS OF BERLIN. MODIFIED FIGURE DERIVED FROM THE POLLEN PROJECT

32 Further details can be found on http://www.amsti.org/

Extremely important for the project is the Senate Department of Education, Youth and Science, which contributes with financial support and knowledge of the school system. They funded the acquisition and adaptation of teaching materials. In addition, they allow teachers to work part time for TuWaS!, while being paid by the school system. TuWaS! is also supported by companies. For example Go! EXPRESS & LOGISTICS, which specialises in secure transport of time-critical shipments, delivers and picks up the teaching materials without charge. Companies also helped to buy some of the teaching material. The Berlin chapter of the *Junior Chamber International* provided funds to pay for the professional development. In addition, young volunteers (*freiwilliges ökologisches Jahr*) work for the project by helping to adapt the material and organise public events.

Learn to share what you have learned: expand and disseminate but adapt to local circumstances

TuWaS! joined the Fibonacci project to increase the number of children benefitting from the TuWaS! model and to assist other projects who wanted to implement a similar initiative (figure 7). The new projects are obliged to follow the concept of TuWaS!—mandatory professional training before using the teaching materials, assisting schools in case of problems. There are also adaptations to local conditions.

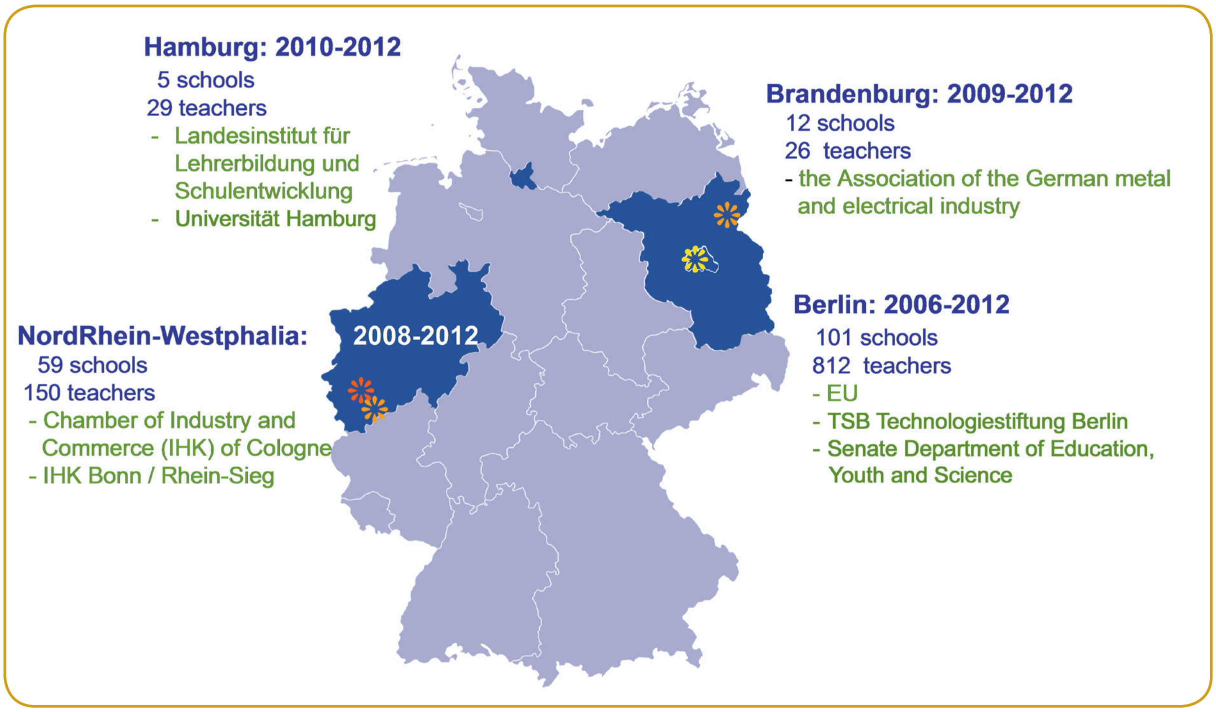

Figure 7: Dissemination of TuWaS! in Gemany and the crucial stakeholders important for implementation

TuWaS! in Berlin was asked by the *Chambers of Industry and Commerce in Köln and in Bonn/Rhein-Sieg* to help start a project in North Rhine-Westphalia (another federal state within Germany). After a yes vote, the Chambers of Industry and Commerce provided seed money and asked their member companies for financial support for particular schools. The seed money funded a part-time post to transfer knowledge from Berlin to Köln/Bonn and to coordinate the programme. The initial professional development workshops and the teaching materials were also funded. So far all the professional development workshops are run by experienced trainers from Berlin and the teaching material is adapted in Berlin. However, in the future, local trainers will be recruited and a local-material centre will have to be developed.

In contrast to Berlin where only a smaller part of the funds are given by industry, in TuWaS!-Köln/Bonn, the funds were provided entirely from industry. Due to these local circumstances, the participating schools in the Köln/ Bonn area do not have to pay a fee to get the teaching material.

The foundation of TuWaS! Köln/Bonn, as well as the collaboration as twinning partner within the Fibonacci project, improved our skills in collaborating with our industrial partners in Berlin and will thus allow us to improve our community board.

TuWaS!-Berlin also started to work in the federal states of Brandenburg, supported by the *Association of regional employers' associations in the German metal and electrical industry* and in Hamburg by the *Landesinstitut für Lehrerbildung und Schulentwicklung* (regional institute of teacher education and school development) and the *Universität Hamburg*.

Lessons learnt:

- Responding to the needs of teachers and schools is important, otherwise it will be hard to recruit the teachers.
- It is important to learn as much as possible from other initiatives because it will speed up the implementation and growth of your own initiative. It is, however, advisable to adapt to local needs, which might differ from those of your partners.
- Programmes grow faster than you might expect, thus look for partners from the beginning to get the work done and ensure financial support.

Concepts on Resources and Materials for Secondary Schools within a Physics Museum

Patricia Corieri and Philippe Léonard, Université Libre de Bruxelles, Belgium

Project start

The Experimentarium (Xp) is the physics museum of the Université Libre de Bruxelles (ULB)[33]. As part of the science department, the museum was developed to enhance the university's visibility and also to preserve and display the collection of original physics instruments of the university. When the Xp was created some fifteen years ago, it used to be a regular science museum with classical activities such as:

- Science exhibitions (recent topics: climate, sustainable development, energy, physics in cartoons).
- Design of experimental activities/workshops.
- Design of physics demonstrations.
- Answering the teachers' demands for specialised visits of the museum.

However, some years ago, our early considerations about the state of science teaching and a growing form of disinterest by young people for scientific careers, met similar observations in Europe. The first European experience at the ULB was the involvement in the Pollen project[34] .

In the frame of Pollen, around 300 teachers were trained to implement inquiry-based science teaching in their classes. In the French speaking community of Belgium, the initial training of primary school teachers is mainly focused on language, mathematics and didactics. Thus they are not confident in terms of science teaching and certainly not familiar with the inquiry-based approach. The Pollen project clearly demonstrated that continuing professional development is the starting point of a larger set-up, and that it should necessarily include tutoring after the training, organised around a focal point that is the resource centre. It also implies that the resource centre is a place where the teacher can find, not only material, but also support and ideas on how to implement inquiry-based science and/or mathematics teaching.

Using the Experimentarium as a resource centre

The obvious starting point of the Fibonacci project was to stimulate new ways of teaching and, accordingly, more interest for science from young people. The resource centre at Xp has been developed along the same tracks:

- Experiment-based activities.
- Interesting challenges to solve.
- Scientific models built from experimental evidence.
- Building personal confidence and evaluation capacity through effective measuring of reality.
- Ability to use modern technology.
- New forms of assessment.

The design of the didactical activities has to take all these aspects into account to integrate the scope of the project. Let us say that a good challenge design idea has to be seconded by the right choice of material and obviously needs to be assessed on the same level of "competence". That is why the resource centre should function as a helpdesk; we lend the sets of experiments to the teachers only after further training, in order to make the exchange beneficial enough. We also tutor the teachers to help them manage the lessons. The Fibonacci project has generated a larger revamping of the didactical environment of our science lessons through the systemic inquiry-based approach. Since we had chosen to focus on the secondary teaching level, the top-down approach allowed us to develop even more cross thinking and introduced more interesting updates to the resources used for primary sources. We also favour the links with the industry; our labs often use materials designed by the industry to enforce the relations between applied science and knowledge.

33 Further details can be found on http://www.experimentarium.be

34 Further details can be found on www.pollen-europa.net/

Design of new materials and experiments targeting secondary schools

When Fibonacci started in 2010, the Xp was chosen to implement a resource centre with a focus on secondary schools. Secondary schools appear as a completely different challenge compared with primary schools. We feel that the first years of secondary (12 to 15 years old students) are the most deprived of quality in scientific teaching, especially in respect to inquiry-based science teaching and applied science. As a consequence, the first tasks of our resource centre were the design of our own didactical material to reach a full innovative set of inquiry-based science lessons usable for secondary and technical teaching classes.

Most of the ideas for the project are based on the experience and links with the science education in Belgium, gained through the Xp visits, workshops and our teaching experience in secondary schools.

By using TIC, instrumentation such as sensors and computers is very important and thus more appealing for students in secondary schools because they want more up-to-date technology. Experimental work should be designed to allow fast and easy data collection AND more time to think about how to use the instruments in a better way and WHAT conclusion to dig out of the data. We use a lot of sensors and other modern instrumentation and the students are usually quite quick to understand how to use them.

We also use "Challenge labs". These experiments follow the format already used in the USA for several years[35]. Experiments must be challenges with each student team having one question to solve. Each team also receives a set of sensors and instruments for that purpose. This is very different from the science kits including ad hoc material. The sets should include more equipment than actually needed in order to allow for a real choice. These short activities are also adapted for evaluation.

Another important change we have introduced in our proposed lab activities is to deliberately omit the reference to graphs. Indeed, most lab activities require the students to do some graph analysis to be able to reach conclusions. However, if they do so, the students lose the benefits from the inquiry strategy. It is quite clear that giving less indication on how to reach the objective will eventually give them much more insight and method, even if this may require more time and preparation. We often use the "coffee filter falling" experiment.

We restructured the experimental activities with our hands-on lessons not being just pure inquiry. We prefer to use a step by step approach in order to reach the challenging question. That means providing the ways to experiment properly (e.g. by changing one parameter at a time) and collect the basic important information. Then the students have to solve the "Terra Incognita" which is a transfer/bridging activity and truly at the heart of the inquiry-based lesson. For example, students examine the link between the energy of a projectile and the width of a crater it creates by falling into the sand. The "Terra Incognita" asks for the size of the meteor that created the "Barringer" crater in Arizona.

These labs are part of the workshops proposed to the classes at the Xp and they are also used by the teachers in their classes with the accompaniment of the resource centre. The range of topics we have developed include optics, electricity production and control, thermal insulation techniques, sound and light activities, waste recycling, substance sorting and identification, energy transformation and efficiency, time measurements, air and water quality and communication systems.

Challenges and solutions for implementing inquiry-based science education in secondary schools

To train the teachers and provide adequate tools, we had to overcome some difficulties:

- **Age:** Between 12 and 15 years old, students may become less interested in science and their behaviour can be difficult to manage.
- **Class managing:** Occasionally teachers find the students noisy and sometimes uninterested. To succeed in managing the class, some teachers give discipline priority to experimenting. These teachers are naturally opposed to inquiry-based teaching. They fear losing control.

35 Jones, D., 2009. Time Trials—An AP Physics Challenge Lab. The Physics Teacher. 47 (6), pp. 342.

- **Difficult transition:** going from a primary school (more family-like) to a secondary school also leads to a change of attitude among the students.
- **Curriculum:** Teachers oppose the inquiry-based approach according to the large requirements of the curriculum. Inquiry-based teaching methods are considered too time consuming to allow full coverage of the official curriculum. When asked to teach a subject on the basis of experiments, they believe that they also have to redo their lecture in a classical way to fix the concepts. It is difficult for them to realise that a concept can be understood through experimenting.

To overcome the challenges, a main point is to design interesting challenges for the students and give them **responsibilities** to reach the solution. They have to make choices and use some kind of scientific strategy to reach it. Using modern technology and instrumentation combined with team work is obviously one of the best ways to run scientific projects and make them feel part of them.

A good example is the workshop "No panic in the village", which is given to whole classes. A miniature village offers different student groups different challenges to solve; some will try to lighten the football terrain with as much light and less money as possible, while some other groups will take responsibility of analysing the water quality in the village. This particular workshop involves many sophisticated instruments (pyranometers, luxmeters, wattmeters, pH-meters, etc.) and requires good teamwork to solve all the questions. At the end a debriefing allows the whole group to realise its global level of performance in the environmental managing of the village.

Development of assessment methods and curriculum orientation

To face the arguments of teachers who are opposed to inquiry-based teaching because of the already heavy demands of the curriculum, we are involved in developing new assessment methods. Regarding the curriculum, we are part of the working groups of the Board of Education which defines new directions and the specific inquiry orientation given to maths and science lessons that will be mandatory over the next years. The development of experiment-based lessons and the definition of new assessment methods are among the main objectives of this programme.

The curriculum guidelines in Belgium impose the application of the inquiry-based methods. So far, however, no clear instructions have been given to evaluate the knowledge and the methodology acquired. We have addressed these difficulties in our project by integrating specific advice and discussion in the training sessions. The assessment question can be partly solved by the challenge labs activities.

Continuing Professional Development

We provide half-day training sessions for teachers and future teachers limited to 25 participants. The teachers are asked to solve exactly the same problems as the ones they would subsequently give to their students. This immersion is of course essential to develop enough confidence in the inquiry process in general, and specific questioning relative to the specific subject. Each workshop is accompanied by a debriefing and hand-outs.

Lessons learnt:

- Primary and secondary schools need different tools for inquiry-based science and/or mathematics practice because their time and task management is completely different.
- The evaluation, in direct link with the curriculum imposed to the teachers, has a large influence on their teaching. We have to implement assessment methods within the activities we developed.
- Training and resources have to be adapted to the initial training of the teachers. The use of more modern instrumentation and genuine inquiry-based methods still has to be extended.

Implementing Inquiry-based Science Education with Low Budget and High Community Involvement

Stevan Jokić, VINČA-Institute, University of Belgrade, Serbia

The starting point: providing resources for teachers without any financial support

Keeping in mind the science teaching in Serbian schools and the bad results of our students in the PISA test, we had the vision of changing the situation in science education and thus founded our project "*Ruka u testu*" in 2001. Inspired by the experience in other countries such as France with *La main à la pâte*[36], Sweden with NTA[37], China with *Learning by doing*[38], Great Britain with *XXI Century Science*[39], we started to introduce our hands-on approach. The initial idea came from in a meeting with the French academics Pierre Lena and Yves Quéré and other members of the French team L*a main à la pâte* at a symposium in Serbia.

Figure 8: FIVE BOXES CONTAINING MORE THAN 20 EXPERIMENTS AND TRANSLATED BOOKS

Our strategy was to achieve scientific literacy for all children by creating different resources for teachers. This idea was new in Serbia, as in many other countries. At the beginning we did not have any financial support. For that reason we decided to translate as many of the books for teachers and parents created by the team *La main à la pâte* as possible which are, in our opinion, excellent. Additionally, we had many *appendices* in the Serbian Educational weekly journal *Prosvetni pregled*, which is distributed, free of charge, in Serbian schools. We also did this without *any financial support*.

All the French resources were given free of charge, not only for translation, but also as a basis for the later creation of our experimental kits and our website. The next logical step was to respond to the needs of teachers. We implemented our website (http://rukautestu.vinca.rs), to give more teachers access to our science and educational resources. With relation to the concept of our website, we again profitted from the experience of L*a main à la pâte*. When setting up a centre, learning from the experience of partner projects is very important.

Since the end of 2008 the Serbian website has been online and contains about 2,500 pages, which offer teachers many important resources. These include numerous modules for activities in the class. Some of these were created by Serbian teachers in collaboration with researchers and through interdisciplinary projects. Additionally, there are pedagogical documents from elementary to low secondary school (e.g. "integral teaching of science" and the modules "matter and materials" and "energy and energies"). The website also includes a discussion platform for teachers where questions can be addressed to other teachers or scientists.

A growing project: creation of own resources, establishment of teacher networks and dissemination of inquiry-based science education

In the beginning of the project, we found that a small, enthusiastic team was needed in order to give a fresh impulse to inquiry-based education. Our team includes about 20 members from schools all over Serbia, professors from universities and scientists from research institutions. They all have experience in science education and are highly motivated to introducing inquiry-based teaching in our country.

In the framework of the Fibonacci project, we implemented inquiry-based science education with the support of the Serbian Physical Society and in collaboration with the French Academy of Sciences.

36 Further details can be found on www.fondation-lamap.org/en

37 Further details can be found on http://www.nta.kva.se/In-English/

38 Further details can be found on http://www.rcls.seu.edu.cn/en/

39 Further details can be found on http://www.twentyfirstcenturyscience.org/

To make use of our experience in teacher workshops of the last six years, as well as of our resources, we decided to develop our own pedagogical kits for primary schools. For the kits we use only low budget materials but we received financial support from the Fibonacci project for teachers who work within the projects.

Until now, kits were developed on the following topics: *air, water, electricity, colour, floating and sinking*. In addition, prototypes were developed on "*senses*" for preschool with 10 experiments on "*climate*" and "*my planet and me!*". Our collaborators created two modules on the topics of "*sound*" and "*classification*" which are available on our website.

In order to work with the pedagogical kits for primary schools, our team established 14 regional experimental rooms in Serbia (figure 9). Each Room is supplied with 5 boxes containing 20 experiments for class activities and 10 books. These 14 centres serve about a hundred primary schools. Our aim is to give teachers a model of research and implementation of inquiry-based teaching in a convenient place with convenient tools. The booklets explaining the experiments of the kits can also be downloaded from our website (free of charge).

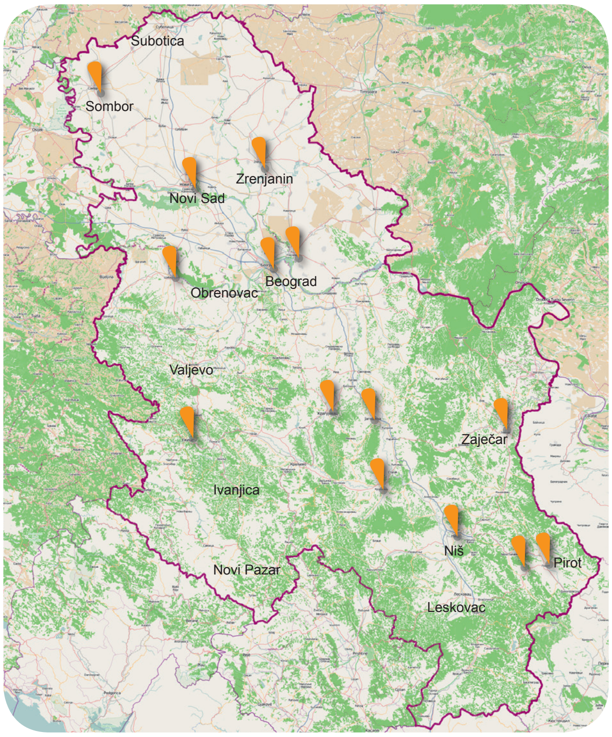

FIGURE 9: MAP OF THE 14 REGIONAL EXPERIMENTAL ROOMS IN SERBIA. © OPENSTREETMAP CONTRIBUTORS

Besides providing resources for teachers in Serbia, we focus on establishing a network of Serbian schools interested in participating in the Fibonacci and Greenwave[40] projects. Nearly 50 schools, primary and secondary, have joined the project. We have chosen schools which are geographically close to one another for a better involvement of local actors. We cover almost all areas of Serbia, which is very important for he dissemination of inquiry-based science education across the country.

These and other pedagogical projects offered on our website open the door to teachers for an interdisciplinary approach and participation in different international activities. This is an important step which encourages the sharing of experience and the development of national and international networks.

Continuing Professional Development: providing one-day courses for teachers

Eight-hour sessions of professional development, accredited by the Ministry of Education, were organised for more than 1,000 teachers and tutors in 2010/11. The participants are trained to implement inquiry-based science education. As with their pupils in elementary and lower secondary schools, they have to find the answers to questions on different topics by using material easily found in their surrounding world or by using our kits. The workshops are held in the schools, in about 30 places all over Serbia. Thereby teachers of preschool and elementary school were trained together with secondary science teachers in order to develop teamwork between schools and bridging the gap between the scientific disciplines. Our aim was to demonstrate to teachers that it is possible to implement inquiry-based teaching at all levels of schooling. During the project, trainers are in touch, and each of them is responsible for up to 10 teachers. We get support by students from the teachers faculties who do their practical training in our schools. In addition, the Ministry of Education introduced the optional subject in "Hands-on-Discovery of the World" in 2003.

40 Further details can be found on http://www.greenwave-europe.eu

Mobilising decision-makers and a local support network to ensure the project's viability

Establishing a local support network and mobilising decision makers are key elements of support. They could overcome a lack of financial support in the start-up phase. By translating the resources of *La main à la pâte*, we fostered the communication among French and Serbian scientific-educational community. As we were without any financial support at the beginning of our project, we contacted and then presented our project to a number of university professors, to scientists from different institutes and to school teachers. As a result, we received various forms of support—assistance with translating, scientific advice and shared experience.

Furthermore, a partnership with several institutions within various fields was developed. This encouraged support across the board which provided further support in planning international workshops from the Academy of Sciences and Arts, the Serbian Physics Society and the Serbian Ministry of Education.

Five Southeast European workshops on "*hands on primary science education*" were organised in Belgrade from 2005 to 2010. Participants who were members of the Fibonacci Project, scientists, science educators and education experts, professional advisors and policy makers took the chance to exchange and extend on their experience. http://rukautestu.vin.bg.ac.rs/handson4/.

We found a school publishing house (Zavodzaudzbenike) and a weekly educational journal (Prosvetnipregled) which published all our books for free.

The French Academy of Sciences signed an official collaboration document for our project with the Serbian Academy and the University of Belgrade. In addition the French Embassy in Serbia supports our activities. Throughout 2010/11, the VINČA team members, teachers and students involved in the Fibonacci Project in Serbia gave several interviews and made guest appearances in broadcasts on Radio Belgrade 1 (*Serbian National Broadcasting Corporation*). The main goals of those participations and interviews were to present and promote inquiry-based learning, the Fibonacci project in Serbia (including the Greenwave Project), as well as new methods and approaches in the teaching of science.

Assessment and evaluation is planned in the near future

We are developing tools for formative assessment of teaching practices and student learning. We are presently handing out to our teachers "self-reflection questionnaires" created by the Fibonacci team, which were translated for our teachers. In order to measure the project's impact on classroom practice, a PhD thesis at the Faculty for Teachers in Sombor has been started.

Challenges: The main obstacle beside the financial shortage, is our society's inertia against change in education. In our opinion, the main aim of the primary school should include *scientific literacy for all children*. Still, teachers mainly present science via lecture—the belief that children very rarely resolve experimental problems or projects themselves and parents are mostly interested in children's grades and not competencies and skills. Even the scientific community did not completely accept that school must be orientated towards all children, and not only to the more "gifted" ones. Therefore in our opinion a CSME introducing inquiry-based education will only be sustainable with the strong support of the Ministry of Education.

Lessons learnt:

- In the beginning you need a small enthusiastic team in order to inject fresh impulse into inquiry-based education.
- When setting up a centre, learning from the experience of partner projects is very important.
- Establishing a local support network and mobilising decision makers are key elements of support. They could overcome a lack of financial support in the start-up phase.
- An education project will only be sustainable by the strong support of the Ministry of Education.

Teacher Networks as a Success Factor within a Large Scale Project

Dagmar Raab, University of Bayreuth, Germany

The national projects SINUS and SINUS Transfer

As a consequence of the disappointing German results of the Third International Mathematics and Science Study—(TIMSS, 1996/97)[41], the pilot study "Increasing Efficiency in Mathematics and Science Education" (SINUS) was launched in 1998.

180 German schools participated in SINUS from 1998 to 2003. As a result of the very positive evaluation, the follow-up project SINUS-Transfer was started and has brought the SINUS approach to a great number of schools and teachers all over Germany. About 1,800 schools and more than 10,000 teachers participated between 2003 and 2007.

The central support for achieving SINUS and SINUS Transfer was done by the Leibniz Institute for the Pedagogy of Natural Sciences at the University of Kiel (IPN) in cooperation with the Chair of Mathematics and Mathematics Education at the University of Bayreuth and the Institute for School Quality and Education Research in Munich (ISB). The SINUS schools were mainly supported by the so-called coordinators who worked closely with the above institutions.

SINUS Transfer is the largest school development project that has ever been carried out in Germany.

Eleven modules as a common framework

Teachers in the programme are seen as the experts in teaching and learning who are capable and responsible for further developing and improving their own classroom teaching. The SINUS concept is based on an array of problem areas (the so-called modules) which may arise in maths and science lessons. Those areas frame the work of the teachers involved and allow them to act in a self-directed and cooperative way.

The modules leave room for supplementation and individual development, but are clearly embedded in a basic concept. They are based on an in-depth analysis of science and mathematics education[42]:

1. Developing a task culture
2. Scientific working
3. Learning from mistakes
4. Gaining basic knowledge
5. Cumulative learning
6. Interdisciplinary working
7. Motivating girls and boys
8. Cooperative learning
9. Autonomous learning
10. Progress of competencies
11. Quality assurance

Teachers working on those modules have access to scientifically-based materials and worked-out examples referring to the modules. Guidance by the coordinators and in-service training is also based on the modules.

41 Further details can be found on http://timssandpirls.bc.edu/timss1995.html

42 Further details can be found on http://www.sinus-transfer.eu

Cooperation as the main objective

Cooperation and collaboration on different levels amongst teachers play an exceptional role in the SINUS philosophy. Cooperation takes place within the department of a school, and also beyond the individual school. Exchange of ideas and experiences on a state level and supervision and support on an interstate level promote and strengthen cooperation with local implications. In addition, the teachers cooperate both in an intra and inter-disciplinary manner.

This concept of intensive cooperation was very new in Germany and one of the main factors of the great success. It was also highly appreciated by the participating teachers.

Networks as structuring elements

However diverse and flexible the topics and the individual work at school may be, such a large scale project needs very clear structures to ensure successful work within common goals. This has been achieved by networks on different levels.

Six to ten participating schools (SINUS network schools) are grouped around an experienced school (pilot school). The teachers receive advice and practical support from the so-called set coordinators, who are mainly science and mathematics teachers of the pilot schools. The set coordinators are also responsible for organising training sessions and support from external experts (figure 10). Each school set is located in the same town or region allowing intensive cooperation and continuing exchange of experience.

All school sets are part of an overarching states' network (figure 11). The responsible states' coordinator stays in contact with the central coordination and participating institutions such as universities and ministries. Regular meetings of all states' coordinators ensure effective work including discussion and integration of new educational aspects.

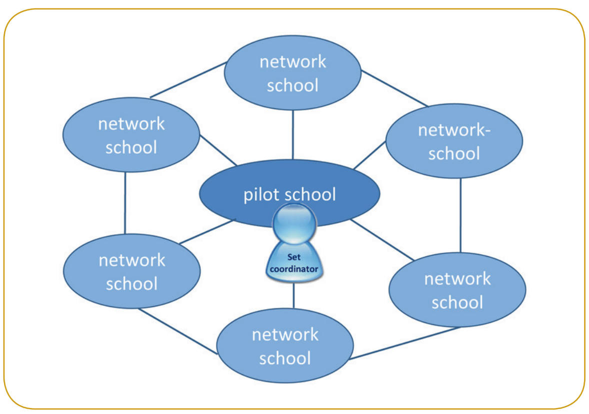

FIGURE 10: SCHOOL SETS

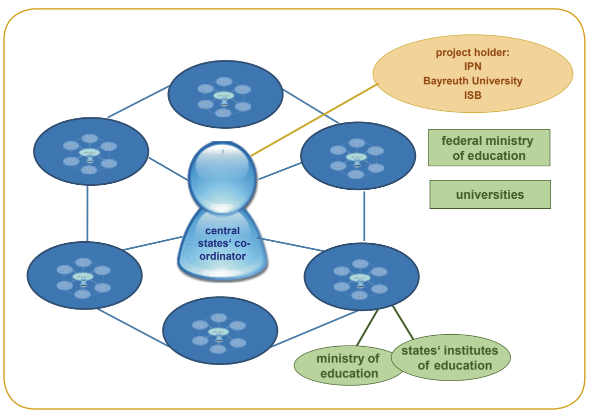

FIGURE 11: OVERARCHING NETWORK

Fibonacci as follow-up project – international cooperation

When looking for successful projects for improving science and mathematics education on a European level, the European Union also recognised the SINUS programme as a very innovative and successful pedagogical approach. The Rocard Report recommends SINUS as a model for a large scale European project aiming at improving science and mathematics education. "The impact of Sinus-Transfer is very positive. The evaluations conducted show a significantly positive impact on student attainment, especially for weaker students. Large numbers of teachers have shown strong support and enthusiasm for this initiative".[43]

43 European Commission, 2007. EUR22845, Science Education NOW: A renewed Pedagogy for the Future of Europe Luxembourg. Office for Official Publications of the European Communities, pp 16/17.

As recommended, main parts of the Fibonacci project are based on the SINUS philosophy. So it was highly appreciated by the project partners to get in contact with experienced teachers from the well-established German networks. Those teachers worked as trainers in international workshops, showed practical examples and discussed intensively their intentions, experiences and also obstacles. The German teachers involved are very satisfied to get the chance to stay in contact with other European teachers, educators and researchers and vice versa. New aspects, materials and intensive discussions about common issues bring an additional wind of change to the individual and set school work. In this context it was important to get strong support from the Bavarian Ministry of Education. About 30 Bavarian teachers are paid by the Ministry of Education for their work as set coordinators in the Bavarian side of the Fibonacci project. The University of Bayreuth is responsible for training sessions for the coordinators, cost-free materials like the maths bag[44], books, articles and interactive tools.

SINUS international: examples in English language

To spread the ideas on an international level, it is important to offer materials in a common language. So we sifted through the big number of resources to provide good practice and background material. Paid by the Federal Ministry of Education, selected materials were translated into English and are available for free[45], especially the booklet SINUS Bavaria which reflects the existing diversity of the work being done in different school types, school groups, and subjects and is exclusively written by experienced teachers[46].

FIGURE 12: SELECTED MATERIALS WERE TRANSLATED INTO ENGLISH

Sustainability—national educational standards

One of the most important outcomes of the SINUS projects so far was the implementation of national educational standards for mathematics and science. Those standards are compulsory for all schools (primary and secondary) all over Germany. They heavily focus on the eleven modules and outcomes of the SINUS projects taking into account inquiry-based methods, motivation and activation of students, increased connections to real world problems and methods for fostering independent, self-organised and team-orientated learning.

Lessons learnt:

- Respect teachers as experts of teaching and learning.
- Common goals including freedom for individual adaptations lead to high acceptance.
- Successful and sustainable changes need long-term projects, a crucial number of participants and a high recognition and assistance from the responsible institutions.

44 Further details can be found on http://em.uni-bayreuth.de/mathebeutel/

45 These materials can be found on www.sinus-international.net

46 http://sinus.uni-bayreuth.de/math/ISB_SINUS_Bavaria.pdf

Operating and Evaluating Regional Networks, a Project Initiated by the Government

Franz Rauch and Gertraud Benke, Alpen-Adria Universität Klagenfurt, Austria

The IMST project

The nationwide project 'IMST' (Innovations Make Schools Top) aims at improving instruction in mathematics, science, IT, the German language and related subjects. The focus is on students' and teachers' learning[47].

Since 1998, the project has been repeatedly commissioned by the Austrian Federal Ministry of Education, Science and Culture to the Institute of Instructional and School Development (IUS) at the Alpen-Adria-Universität Klagenfurt. It developed in three phases: (1) analysis of the disappointing Austrian results at the Third International Mathematics and Science Study (TIMSS 1995)[48]; (2) development of the IMST project (2000–2004); (3) build-up of a school support system (2004–ongoing). Since 2004 IMST has encompassed the entire educational system (K-12 and teacher education). Currently about 21,000 teachers are involved who participate in projects or cooperate in networks.

The IMST programme 'Regional and Thematic Networks' supports regional networks in all nine Austrian provinces, and three thematic networks which operate on the national level. Within the IMST thematic programmes, teachers put into practice innovative instructional projects and receive support in terms of content, organisation and finance. Furthermore, 18 Regional Educational Competence Centres (RECC) in science subjects were implemented all over Austria to act as a cooperative structure between universities and teacher education colleges. They partly fill the gap of a lack of subject didactic centres in higher education throughout Austria.

IMST and the strategies to implement inquiry-based science and mathematics education

During its quite long duration, IMST has strengthened all the strategic areas necessary for improving the educational system, Continuing Professional Development and support (CPD) and gives teachers access to resources, community involvement, assessment/evaluation, and creating teachers networks.

With respect to CPD, courses for teachers in mathematics and science are organised. These four-semester courses called "PFL—Pedagogy and Subject specific Instruction for Teachers" are based on the hypothesis that firstly, learning and teaching innovations are supported best when developed in close connection with teaching practice, and secondly, when teachers are investigating their own work and networking with each other and with the academic community (action research). The teachers further develop their teaching knowledge and competences as well as their theoretical understanding.

Teachers participating in the IMST programme are engaged in different sub-programmes (currently by thematic programmes on competency, experimental learning, IT, assessment for learning). Within these thematic programmes, the teachers were coached and received learning materials for their classroom projects. The participants –individual teachers, teacher groups, whole schools or local school networks– had to report on their activities. Over the years, IMST therefore accumulated a rich data base consisting of project reports stored in the IMST-Wiki. They contain reflections on teaching and learning processes.

47 Further details can be found on www.imst.ac.at

48 Further details can be found on http://timssandpirls.bc.edu/timss1995.html

Regional networks

The regional networks (RN) are, in addition to the Thematic Programmes, an important part of the project. "Regional" refers to each of the nine Austrian federal states. As of July 2012, such regional networks supported by IMST exist in all states. Furthermore, 18 Regional Educational Competence Centres (RECC) for science education (in biology, chemistry and physics) were established all over Austria to act as a cooperative structure between universities (responsible for the education of grammar school teachers) and teacher training colleges (responsible for the education of primary and lower track secondary school teachers and continuing education with a tradition in vocational experience). The RECC as regional centres of expertise in subject instruction, work closely together with the RN with a focus on networking and exchange.

The goals of the networks are threefold:

- Raising the attractiveness and quality of lessons in mathematics, biology and ecology, chemistry, physics, information technology, geography, descriptive geometry and related subjects, as well as promoting cross-curriculum initiatives and school development in grammar, vocational and secondary modern schools, primary schools and kindergarten.
- Professional development of teachers.
- Involving as many schools as possible.

The formation of regional networks is based on two principles:

- Use of existing personnel, institutional and material resources in the federal provinces.
- The persons, organisations and school development act autonomously and take over responsibility for the development of regional networks.

IMST supports the setting up of steering committees in each regional network to coordinate the generation of content and to create cooperative structures for schools, the educational authority, as well as teacher training colleges and universities (figure 13). In order to facilitate a sustainable grounding of regional networks in their respective federal states, the financial support of IMST is conditioned by raising additional financial or personnel support in each of the federal states (i.e. teaching hours, funds for further education) as well as local industries (i.e. support of projects and network conferences).

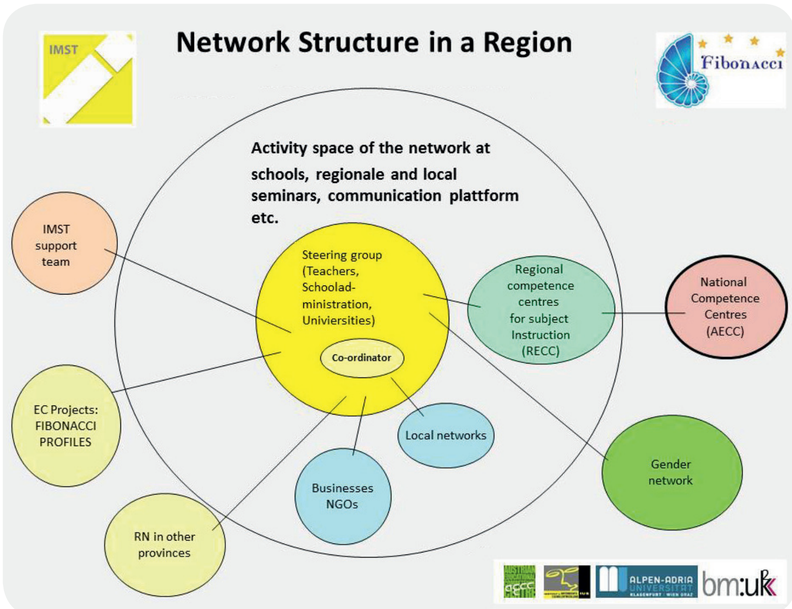

Figure 13: Network structure in a region

The exact task profile of a regional network is geared towards the needs of the respective schools in the region and the existing resources, and it depends on the vision of the people comprising the local steering committee. It encompasses the establishment of a platform for schools and teachers, the organisation of the opportunity for exchange of experiences and further education, the support of creating concentrations and their development in schools, the development of a pool of experts to advise on instructional and school matters, drafting an annual report and interim reports on the activities of the regional networks and the implementation of an evaluation.

The networks and the RECC are supported by the network-team at the IUS at the University of Klagenfurt via a platform for ongoing process management, two seminars per year for members of the steering committee and leaders of the RECC, public relations (folder, newsletter), accompanying research and studies on the development of networks through the team of networks. Thus the local needs and developments are balanced by a national exchange of experiences and endeavours.

Evaluation measures

Evaluation is a central element of IMST. IMST can be described as a cooperative structure between schools, school administration, universities/teacher training colleges and businesses coordinated by the IUS at the Alpen-Adria-Universität Klagenfurt. Like every sub-programme within IMST, the regional networks are assessed by self and external evaluation. The individual regional and thematic networks each submit an annual written documentation, including an evaluation in accordance with the cooperation's agreement. The RN leadership team documents the working process consulting in a log book and gathers written and verbal feedback on the network seminars. In addition a series of interviews were commissioned regularly. As of now about 70 reports have been submitted from regional networks.

The results might be summarised as follows: social contacts prove to be indispensible to the creation of structures, the exchange of experiences and mutual learning. Therefore the approach of using and further developing existing regional structures is, so far, successful. Such development, however, needs small steps. The support from state education authorities is essential for the development of regional identities in networks. The duties of the steering committee and its coordinator(s) are diverse and can only be accomplished by teamwork.

With reference to the four functions of networking according to Dalin (1999)[49], namely informative function, learning function, political function and psychological function, the evaluation data collected up to now gives rise to some indicators and examples. Innovative projects are carried out within the regional networks and increase the attractiveness of science lessons with cross-curricular teaching as well as in collaborations between schools.

The dynamic development of RECC is remarkable; they developed out of the networks. In the next few years, the focus will be on constructing collaborative structures between networks and RECCs as well as quality development and assurance through process management, process guidance, evaluation and research.

Lessons learnt:

- Good practice cannot be cloned but exchange of experiences on a personal level supports learning and innovations.
- Teacher Networks offer a goal-orientated exchange process among teachers (*information function*) which supports the professional development of teachers (i.e. fresh ideas for classroom teaching, inter-disciplinary cooperations at schools) (*learning function*).
- Teacher Networks could create a culture of trust, raise self-esteem and risk-taking of teachers (*psychological function*) and could upgrade science at school (*political function*).
- It is necessary to maintain a balance of Action & Reflection (goal-directed planning and evaluation) and *Autonomy & Networking* (analysis of own situation, support by „critical" colleagues at school, IMST-facilitator) in order to set up a sustainable support system for schools.
- Evaluation and Research needs to be orientated towards an iterative connection between an interest in gaining new knowledge and a developmental interest. A culture of self-critical and collective reflection might flourish, but this reflection should not hamper the progress of the project.

49 Dalin, P., 1999. Theorie und Praxis der Schulenwicklung. Neuwied: Luchterhand.

The Needs of Teachers are Central, but Evaluation and Assessment are Equally Important

Ana Gostinčar Blagotinšek, University of Ljubljana, Slovenia

At the beginning: supporting teachers with their daily work

The involvement of the Faculty of Education of the University of Ljubljana[50] in the Pollen project in 2006 was devoted to supporting inquiry-based learning and teaching of science at the primary level in order to meet the demands of our teachers. Slovenia has got a national curricula, and science is present at all grades, starting from kindergarten. Primary teachers in Slovenia have to teach all (six) subjects and are usually not confident with their content knowledge in science. They teach mostly biology, but tend to avoid chemistry and physics topics. Our faculty offers Continuing Professional Development (CPD) courses for kindergarten and primary teachers. After visiting our courses, the confidence and attitude of teachers improved, but actual implementation was inhibited by the lack of suitable equipment, which also hindered making science lessons more active.

FIGURE 14: TEACHERS IN STARTING POSITION.
© UNIVERSITY OF LJUBLJANA

Within the Pollen project, we got to know the NTA programme (Science and Technology for All) of the Swedish Academy of Sciences. In addition to providing CPD courses, the NTA centres also lend equipment for the implementation in the classroom. We decided that the Swedish NTA model was something that could also work well in Slovenia. As the content of the NTA units did not fit the Slovenian curriculum and the organisational structure of our primary schools, we decided to develop our own.

Giving teachers access to resources

All the materials developed within the Fibonacci (and previously the Pollen) project aimed to support teachers with their daily routine *within the curricula*. The topics chosen were those that teachers reported to be most problematic for them, either because of the required scientific content knowledge, or because of the materials needed to teach them in class.

Every unit contains didactic materials in addition to a box of adequate experimental equipment for classroom use. Units usually start with assessment of the existing pupils' knowledge and preconceptions, vocabulary building and language development, proceed with familiarisation of the equipment and acquisition of the experimental skills, intertwined with concept building and mind teasers to encourage critical thinking and reflection. Starting points for possible inquiries follow. Suggestions on how to assess acquired skills are added at the end (for the teacher). Materials are partially designed as a teachers' manual and partly as a workbook for pupils. Topics are intended for a week or a science day (3–4 lessons).

Continuing Professional Development

The workshops for the teachers are of two kinds: some are devoted to introducing active learning of science, and others are focused on improving the skills for taking inquiry-based science education into the classroom (inquiry workshops, 4 hours each.). The latter focuses on handling pupils' questions, stimulating interest and

50 Further details can be found on http://www.pef.uni-lj.si

Figure 15: Teachers in a CPD workshop.
© University of Ljubljana

including pupils in the planning of lessons, as well as on strategies of managing the components of inquiry (stages of the process, handling variables, fair testing, summarising and reflecting). Posters and worksheets (adapted from material of the CSME Leicester) to support the inquiry process were printed and distributed. Special care was devoted to show how to progressively develop inquiry skills from kindergarten (or grade 1) to grades 5 and higher. Teachers report that typical "inquiry" in the classroom demands 4 lessons, at least for the beginners.

A single afternoon workshop enables teachers to become familiar with the experiments, use of equipment and contextual background. Didactic materials provided make the implementation in the classrooms easier, and those teachers, who attended workshops, were provided with experimental equipment for pupils to borrow. This was also the most cost-effective option.

Besides primary teachers, kindergarten teachers were also part of the programme right from the beginning. As attitudes towards science are believed to be formed at a very early age, extending to preschool ages seemed to be more than appropriate. Special workshops (and experimental kits) were prepared for them, but many kindergarten teachers attended "primary school" workshops, too. The emphasis of units for pre-school age is on developing skills, necessary later for inquiry-based learning (asking questions, observation, describing, explaining, comparing, sorting, data handling, manipulating objects and equipment).

Growing and expanding: importance of local support networks

Initially the activities were limited to one city, Ljubljana. Teachers from other towns heard and read about the activities, attended the workshops, and borrowed the equipment. Subsequently they wanted to implement the programme in their towns, because the head teachers realised that the involvement was beneficial for the pupils and teachers as their attitude and self-confidence in science improved. Representatives of the Board of Education also supported the activities. The City Council of Kamnik decided to buy a complete set of experimental equipment for their schools and to establish a material centre, thus becoming the second city involved in Slovenia.

Meanwhile the number of the teachers involved grew in Ljubljana, making it necessary to establish a second material centre in Ljubljana. The one located in one of the primary schools for in-service teachers is financed by the Ljubljana city council. The second one remains at the Faculty of Education to run the workshops. Recently a third city, Kranj, also wanted to have a centre and actually joined the Fibonacci project with local support.

The increased number of teachers who wanted to be involved provided good feedback for the team, although it also meant coming across unforeseen difficulties. The team was too small to provide Continuing Professional Development (CPD) to the desired amount. Our faculty did not have enough free facilities to host it. Adapting the boxes became too time-consuming to be managed by only one person. Material and logistic support by local authorities proved to be essential, and it is also a key to sustainability.

As a result of support from the educational committee within the city councils, the operation of the material centres was entrusted to experienced teachers, who were personally involved in the project and devoted to the common idea. Storage and renting is provided by the schools, which take active part in the project, and are paid for from the city budgets. Cooperating with local business enabled us to make experimental kits available for all Slovenian schools to buy. Meanwhile the programme went viral throughout Slovenia; 150 other schools bought sets of the experimental equipment. The didactic materials are freely accessible on our website. Inquiry is now explicitly mentioned in the new Slovenian curricula for science as one of the obligatory approaches to teaching, which is also a result of the Fibonacci project's activities.

Evaluation and assessment

The evaluation of the Fibonacci project in Slovenia was conducted on several levels. Monitoring the development and follow-up of the Fibonacci project was done by external evaluators (EDUCONSULT). An internal evaluation was conducted to assess the teachers' motivation to join our project.

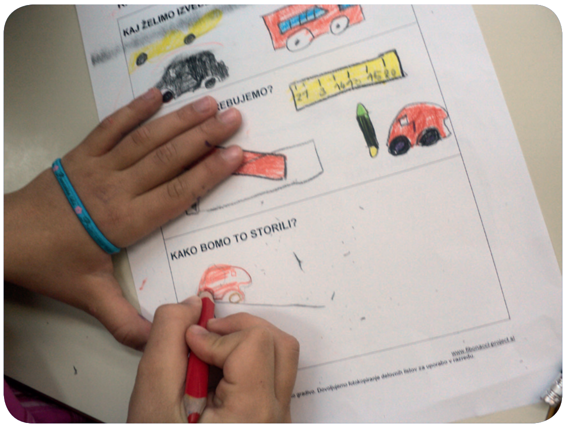

FIGURE 16: KEEPING A NOTEBOOK. © UNIVERSITY OF LJUBLJANA

Evaluation plays an important role in developing and improving our experimental kits. Additionally, we carried out formative assessment by observing the teachers in their classrooms and by teacher reports. The feedback of teachers is crucial for the development and improvement of materials, resources and the CPD. This is an on-going process throughout the project duration.

A third aspect of the evaluation focused on the learning outcomes of the pupils. This was necessary to ensure the support of this new approach of science teaching by the head teachers, educational authorities and parents. It also heightened the self-confidence of the teachers. Pre- and post-tests were carried out on a small group in order to study the cognitive achievements of the children. The acquired knowledge was comparable with a group which was not involved in inquiry-based learning, but improvement in attitudes towards science lessons was frequently reported by the Fibonacci teachers.

Research conducted at the Faculty of Education shows, that providing teachers with tools for evaluation and assessment of the progress of their pupils is crucial for the success of implementing this new approach to teaching. Furthermore, it turned out that the assessment of the achievements of the pupils also determines the nature of teaching[51]. With inquiry-based science education, the focus of learning changes from strict content knowledge (which can be assessed with paper and pencil only) to include competencies and process or inquiry skills. To address these skills, examples of assessment tasks were added to each unit.

Lessons learnt:

- Units and didactic materials have to match the local curriculum.
- Familiar and ready-to-use equipment encourage teachers to take a first step.
- Teachers are at the heart of a reform, but teaching is only the beginning. Evaluation and assessment are equally important. Providing teachers with tools for evaluation and assessment on the progress of their pupils is crucial for the success of implementing the IBSE approach.
- Pupils' (summative) assessment determines the nature of teaching.
- CPD programme development requires feedback to evolve in the right direction.
- Material and logistic support by local authorities is essential, and it is also a key to sustainability.

51 Razdevšek Pučko, C., 1995. Opisno ocenjevanje: teoretična izhodišča in praktični napotki za opisovanje dosežkov pri posameznih predmetih.Only in the Slovenian language.

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Links

AMSTI, Alabama Math, Science, and Technology, USA. Initiative: http://www.amsti.org/

Danish Legislation: https://www.retsinformation.dk/

Ein Beutel voller Experimente, University of Bavaria: http://em.uni-bayreuth.de/mathebeutel/

Experimentarium, Physics museum of the Université Libre de Bruxelles: http://www.experimentarium.be

FAST Project: http://www.hawaii.edu/crdg/sections/science/documents/fasteval.pdf.

Greenwave Project: http://www.greenwave-europe.eu

IMST Project: http://www.imst.ac.at

La main à la pâte Project: http://www.fondation-lamap.org

NTA programme (Science and Technology for all), Sweden: http://www.nta.kva.se/In-English/

Pollen, EU project: http://www.pollen-europa.net/

Research Centre for Learning Science (RCLS), China: http://rcls.seu.edu.cn/en/

Ruka u testu project, VINČA institute, University of Belgrage: http://rukautestu.vinca.rs

Scienceduc, EU project: http://scienceduc.cienciaviva.pt/home/

Sinus bavaria booklet: http://sinus.uni-bayreuth.de/math/ISB_SINUS_Bavaria.pdf

Sinus International: http://www.sinus-international.net

Sinus Transfer Project: http://www.sinus-transfer.eu

TuWaS!-project of the Freie Universität Berlin: http://www.tuwas.fu-berlin.de/

Twenty First Century Science Project: http://www.twentyfirstcenturyscience.org/

University of Ljubljana, Faculty of Education: http://www.pef.uni-lj.si

Annex 1

List of CSME's Involved in the Fibonacci Project and their Strengths

Annotation:
IBSE/IBME: Inquiry-Based Science Education/Inquiry-Based Mathematics Education
Pre-service TE: Pre-service Teacher Education
ISCED: International Standard Classification of Education
ISCED 0: Pre-primary school
ISCED 1: Primary school
ISCED 2 & 3: Secondary school

INSTITUTION RESPONSIBLE FOR THE CSME	TARGET GROUP & ACTIVITIES	SUBJECT	SPECIALITIES AND STRENGTHS OF THE CSME ACCORDING TO STRATEGIC WORK AREAS **IC** = Involving the Community **CPD** = Providing Continuing Professional Development **TN** = Creating and Promoting Teacher Networks **AR** = Giving Teachers Access to Resources **CO** = Cooperating with Other CSMEs **PA** = Programme Assessment **PM** = Programme Management **O** = Other
AUSTRIA University of Klagenfurt Konrad KRAINER Konrad.Krainer@uni-klu.ac.at	ISCED 0, 1 & 2, CPD PRE-service TE	Maths & Science	• **IC:** Link with IMST (Innovationen Macht Schulen Top), national initiative promoting M&S education. • **CPD:** Regional network: regional education competence centres, multiplier—mentor teachers, support teachers. • **TN:** Strong focus on action research reports drafted by teachers, database of good practices. • **PA:** Research on reflection and on evaluation. Exchange between researchers, school authorities, schools, teachers and teacher trainers. Tandems of primary school teachers.

BELGIUM Free University of Brussels Patricia CORIERI pcorieri@ulb.ac.be	ISCED 0, 1 & 2 CPD	Maths & Science	• **CPD:** Organisation of CPD for teachers of schools in deprived areas, mixed areas and privileged areas. • **AR:** Design of own experimental material for IBSE/IBME activities for secondary schools. • **PM:** Strong link with the Experimentarium, the science centre of the ULB. • **O:** Focus on the special needs of disadvantaged schools: Scienthothèque; focus on transdisciplinary approaches including maths + sciences, engineering students as buddies to secondary school teachers, involvement in new official curriculum with emphasis on IBSE.
BULGARIA Institute of mathematics and informatics Bulgarian Academy of sciences Petar KENDEROV kenderovp@cc.bas.bg	ISCED 1,2 & 3 CPD	Maths	• **TN:** Support of school networks: central coordinator + 10 resource teachers/trainers + 40 cascade teachers. • **AR:** Development of pedagogical kits/Special initiatives for gifted children. • **CO:** Cooperation with the National Association of Maths Teachers, links with other international (UNESCO) initiatives, Olympiads, etc. • **O:** Focus on research, very active methodologies combining sciences with IT: cross-disciplinary approaches.
CZECH REPUBLIC University of South Bohemia Pavel PECH pech@pf.jcu.cz	ISCED 1, 2, 3 + VET schools	Maths	• **IC:** Strong link with all innovation activities for sciences set up by the Ministry of Education, strong focus on involvement of the school to promote innovation in maths education. • **TN:** Regional network of schools: central coordinator + 6 mentor (multiplier) teachers. • **O:** Variety of school types involved, also vocational (VET) schools.
DENMARK University College South Denmark Ida GULDAGER igu@ucsyd.dk	ISCED 1 & 2 CPD PRE-service TE	Maths & Science	• **IC:** Support of the development of school didactical plans. • **CPD:** Organisation of CPD sessions for teachers followed by local tutoring of teachers. • **TN:** National coordinators plus regional coordinators support clusters of teachers. • **PM:** Cooperation with National Organization of Centres for Educational Resources.
ESTONIA University of Tartu Toomas TENNO toomas.tenno@ut.ee	ISCED 0 & 1 CPD PRE-service TE	Science	• **IC:** Strong cooperation with the Tartu Science Centre. • **CPD:** CPD credited courses, 12 resource teacher trainers were trained for IBSE, follow-up of teachers trained. • **TN:** Promotion of teamwork within schools, electronic portfolio for teachers as basis for a learning community. • **CO:** Link with national initiative to promote science education, INNOVE. • **O:** Digital portfolio of teachers.

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FINLAND University of Helsinki Hannu SALMI hannu.salmi@helsinki.fi	ISCED 0 & 1 CPD PRE-Service TE	Maths & Science	• IC: Cooperation between formal and informal science education: 3 step IBSE model visit to science centre, pre-activities, visit activities, post-activities. • AR: Development and use of ICT-working tool for the teachers (Moodle). • O: Strong focus on using the external environment of the school to promote science education.
FRANCE Graduate School of Engineering - St Etienne Clémentine TRANSETTI bisson@emse.fr	ISCED 0 & 1 CPD	Science	• **IC:** Cooperation with local, regional authorities involved + financial support, e.g. the science centre (Rotonde). • **CPD:** CPD sessions for teachers focusing on IBSE pedagogical materials/kits available by own resource centre, engineering students tutor science teachers in primary school. • **PA:** Strong involvement in evaluation of IBSE teachers, link with *La main à la pâte*. • **O:** Special focus on disadvantaged schools, science to promote social attitudes and mother tongue.
FRANCE Graduate School of Engineering - Nantes Carl RAUCH carl.rauch@mines-nantes.fr	ISCED 0, 1 & 2 CPD	Science	• **IC:** Cooperation with informal learning organisations: science centres, science forums. • **CPD:** 3-year period CPD strategy: **1)** in-service training days, **2)** follow-up, tutoring in 2 stages: using existing IBSE materials , later on teachers develop own IBSE material. Science and engineering students tutor science teachers in primary and secondary schools. • **O:** Special focus on schools in disadvantaged situations, IBSE to promote social attitudes and mother tongue.

GERMANY Freie Universität Berlin Petra SKIEBE-CORRETTE skiebe@zedat.fu-berlin.de	ISCED 1 CPD	Science	• **IC:** Strong focus on community involvement: different local/regional authorities, companies, federations of industry, informal science labs, financial support of community members. • **CPD:** Compulsory 1 day CPD sessions per topic to enable primary teachers to work one term with the materials. • **AR:** High quality science kits with detailed pedagogical material on 10 topics adapted to the curriculum.
GERMANY University of Augsburg Volker ULM volker.ulm@ math.uni-augsburg.de	ISCED 1 CPD PRE-service TE	Maths	• **IC:** Strong link to SINUS Transfer, strong link with local/regional authorities. • **CPD:** ½ day sessions for large groups (up to 250), smaller CPD sessions in schools involving few teachers, teachers get credits for CPD for professional progression. • **TN:** Regional school network: 17 local groups of 3–8 schools, each 30 teachers coached by 2–3 expert teachers, strong focus on reflection among maths teachers. • **O:** Research in IBE, IBME for gifted and low-gifted children.
GERMANY University of Bayreuth Peter BAPTIST peter.baptist@uni-bayreuth.de	ISCED 2 & 3, CPD PRE-service TE	Maths & Science	• **IC:** Strong link to SINUS (innovation in maths) coordinated by the University of Bayreuth since 1996!, Strong (financial) support from Bavarian Ministry of Education. • **CPD:** CPD sessions to train the regional mentors, support teachers who in turn organise CPD for the teachers in the schools, networking of schools, teachers and mentors/teachers get a certificate important for professional and financial progression. • **TN:** Regional school network: experienced pilot schools build a school set-network with 6-10 schools, a mentor supports the local school network, 40 teachers operate in tandem, strong link with university. • **O:** Research in IBME, focus on interdisciplinary approaches, focus on ICT and IBSME.
GREECE University of Patras Vasiliki ZOGZA zogza@upatras.gr	ISCED 0	Maths & Science	• **IC:** Special dissemination conference to attract more teachers for the future. • **CPD:** 11 detailed modules, teacher takes at least 1 IBSE general + 2 specific modules, follow-up. • **TN:** Strong network or learning community of teachers, used as basis for dissemination. • **CO:** Strong cooperation with OMEP, world organisation of pre-primary education. • **O:** Research on IBSE activities, interdisciplinary approaches, specialised in pre-primary IBSE.

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IRELAND St Patrick's College Cliona MURPHY cliona.murphy@spd.dcu.ie	ICSED 1	Science	• **IC:** Involving participants in the decision making process, looking at 'real' issues and the needs of teachers in the day-to-day reality of their classroom. • **CPD:** Long-term CPD over 2 years, approx. 60–70 hrs, 4 modules, **1)** first teachers get materials **2)** teacher develops materials, follow-up of teachers through 2 visits, CPD is a bridge to a Master's degree, university accredited certificate. • **TN:** Professional Learning Community: support and virtual learning environment, focus on pair or co-teaching.
LUXEMBURG University of Luxemburg Cristina SIRY christina.siry@uni.lu	ISCED 1 CPD PRE-service TE	Science	• **CPD:** 2 CPD courses: **a)** awareness for IBSE **b)** teachers develop and implement IBSE activities **c)** sustainability through learning community for teachers. • **CO:** Strong links with Lux. Science Resource Network to support teachers: lectures + workshops. • **PM:** Example of a whole school approach to introduce and promote IBSE.
NETHERLANDS Hogeschool van Amsterdam Ed VAN DEN BERG e.van.den.berg@hva.nl	ISCED 1 , 2 & 3 CPD PRE-service TE	Science	• **IC:** Special University Bachelor's teaching degree linked to a degree in educational sciences with IBSE, raising awareness for IBSE through student teachers during their placement period in schools. • **CPD:** Creative approach to prepare future teachers to have an impact on teachers in classrooms. • **TN:** Regional networks of schools cooperating with University & University college Amsterdam. • **CO:** Link with other national science promotion activities formerly Bèta Platform activities, nvolvement in Science and Technology Excellency project, 6 schools develop IBSE programmes.

PORTUGAL Ciencia Viva - National Agency for Scientific and Technological Culture Rosario OLIVEIR Aroliveira@cienciaviva.pt	ISCED 1 CPD	Science	• **IC:** Strong link between formal and informal science education, involvement of the network of the national and regional science centres, special initiative to train employers of companies (e.g. Siemens) to promote sciences in the primary schools of their children, involvement of parents (in companies) in IBSE initiatives. • **CPD:** Credits for professional progression, follow-up of teachers in classroom.
ROMANIA National Institute for Lasers, Plasma and Radiation Dan SPOREA dan.sporea@inflpr.ro	ISCED 0,1 & 2 CPD	Science	• **IC:** Cooperation local, community plus French Embassy, organisation of science fairs. • **CPD:** CPD 3 kinds of courses: 3 hour, 10 hour and 72 hour courses (with credits), some accredited by the ministry, focus of CPD with open and distance learning and e-learning. • **TN:** e-learning platform as basis for learning communities, dissemination and valorisation.
SERBIA VINČA Institute for Nuclear Sciences Stevan JOKIĆ sjokic@vinca.rs	ISCED 0, 1, 2 & 3 CPD	Science	• **IC:** Strong focus on community involvement at local, regional, national and international level. • **CPD:** One-day training involving pupils showing what they have acquired. • **TN:** Network of schools in 12 major towns, 14 regional experimental rooms providing kits and materials. • **AR:** Development of own pedagogical kits for primary schools using only low budget materials, 12 topics.
SLOVAKIA University of Trnava Kristina ZOLDOSOVA kzoldos@truni.sk	ISCED 0, 1 & 2 CPD PRE-Service TE	Science	• **CPD:** Long-term CPD 110 hours IBSE course: theory and practice, open reflective lessons for teachers, strong preparation of future teachers as to IBSE, credits for professional progression. • **TN:** Learning community of teachers, close follow-up of teachers, IBSE self-reflection tools. • **O:** Focus on research and in developing IBSE materials.
SLOVENIA University of Ljubljana Ana BLAGOTINSEK ana.gostincar@guest.arnes.si	ISCED 0 & 1 CPD	Science	• **IC:** Close cooperation with community partners (network of towns) and external partners including financial support. • **CPD:** Credits for professional progression. • **AR:** Material centres provide self-developed didactical material and experimental equipment, resource teachers supporting other teachers. • **PA:** Strong focus on reflection, self- evaluation of IBSE activities, research on IBSE.

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SWEDEN Royal Swedish Academy of Sciences Gerd BERGMAN gerd.bergman@kva.se	ISCED 1 & 2 CPD	Science	• **IC:** Strong focus on cooperation with local authorities, strong links with academy of sciences. • **CPD/TN:** CPD short and longer one-day sessions, CPDs with smaller reflective subgroups (learning communities). • **AR:** Education kits with detailed pedagogical material. • **PA:** Strong focus on enhancing active reflection and involvement of teachers, using self-evaluation tools, • **O:** Focus on inner city schools.
SWITZERLAND University of Zürich Peter GALLIN peter.gallin@ife.uzh.ch	ISCED 1, 2 & 3	Maths	• **CPD:** CPD two steps: **1)** large seminar **2)** seminar for only small groups, follow-up through reflective meetings. • **TN:** A learning community of teachers is created, reflection groups of teachers. • **PM:** Example of a whole school approach to introduce and promote IBSE. • **O:** Applying mathematics with Dialogic learning developed by Peter Gallin, special focus on the use of a learning diary.
UNITED KINGDOM University of Leicester Tina JARVIS jar@leicester.ac.uk	ISCED 1 & 2 CPD PRE-service TE	Maths & Science	• **IC:** Strong involvement of local and regional authorities/partners, e.g. regional science museums, science learning centre. • **CPD:** Long-term CPD sessions, 4 hour workshops, follow-up of teachers through 2 visits, teachers involved link up with a Master's degree, work in Fibonacci is part of Master's work. • **PA:** Evaluation of IBSE/IBME activities, reflection of teachers, action research of teachers involved in CPD. • **O:** Research into IBSE, strong focus on interdisciplinary approaches M & S, e.g. poetry and science, etc.

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

Credits

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Summary

This booklet aims to support entities who are interested in setting up, developing or expanding a Centre for Science and/or Mathematics Education (CSME), which takes inquiry-based education to the classrooms of the local schools at a city, district, county, or regional level.

The booklet comprises two parts. Part I provides an organisational framework for establishing and coordinating a CSME. The framework comprises strategies and recommendations as well as lessons for practice in seven strategic work areas:

- Involving the Community
- Providing Teacher Professional Development
- Creating and Promoting Teacher Networks
- Giving Teachers Access to Resources
- Cooperating with Other CSMEs
- Programme Assessment
- Programme Management

Part II includes nine selected profiles from CSMEs that were involved in the Fibonacci project (www.fibonacci-project.eu) from 2010 to 2013. These profiles provide an overview of how the strategies and recommendations described in Part I can be implemented, adapting them to specific cultural, political, and educational contexts. Lessons from practice are also drawn from each of these initiatives. An overview of the specialities of other CSMEs that took part in the Fibonacci project is provided in Annex 1, thus giving the reader the opportunity to identify and contact potential collaborators.

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