Teacher Professional Development in Pre-Secondary School Inquiry-Based Science Education (IBSE)

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A report prepared by Dr. Wynne Harlen on the International Conference on Teacher Professional Development in Pre-Secondary School Inquiry-Based Science Education (IBSE) which took place in Santiago, Chile, 20-22 October 2008. The report incorporates a revision of the background paper produced for the conference, the outcomes of the discussion and the conclusions and recommendations agreed by conference participants. Reports from the countries represented at the conference will be published on a CD.

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Introduction

One of the global activities of the Inter Academy Panel (IAP) on International Issues, following the decision of the Academies to collaborate in the improvement of pre-secondary[1] school science education, was to consider and make recommendations about the professional development of teachers in inquiry-based science education (IBSE). The decision to give this priority was an outcome of the international conference on evaluation of the implementation of IBSE programmes held in September 2006 in Santiago, Chile. Planning for an international conference on teacher professional development began at a meeting of the evaluation project's International Oversight Committee in October 2007, held in London. Planning continued in January 2008 in Santiago at a meeting concerned with the IAP's global programme on science education (see Appendix A). The objectives of the conference were identified as being:

- To consider a range of approaches to professional development for those involved in implementing IBSE and evidence of their effectiveness.

- To reach a consensus about the essential elements that should be included in programmes of professional development in IBSE for those involved in elementary school education.

- To make recommendations about the content, resources and structure of programmes that provide for continuing professional development in IBSE for those involved in elementary school education.

- To stimulate international collaboration in professional development in IBSE among the national and regional programmes linked to IAP.

- To promote research and evaluation activities in relation to professional development in IBSE.

In preparation for the conference a background paper was prepared, circulated and discussed within the planning group, as a starting point for the conference dialogue. This enabled the main focus of the conference to be on interchange of experience among the invited participants from all parts of the world, who were expert in providing professional development in science education. Participants were also asked to prepare short accounts of key aspects of their professional development work for inclusion in the conference papers. The conference, sponsored by the Inter Academy Panel, the FEMCIDI Program of the Organization of American States, IANAS, the University of Chile, the Ministry of Education of Chile and the Wellcome Trust, took place in October 2008 in Santiago. The program is given in Appendix B and the list of participants in Appendix D.

This report begins with a re-statement of the rationale for IBSE at the pre-secondary stage of education and in Section 2 presents arguments for the importance of professional development in changing practice in science education. Sections 3 to 6 comprise a further revision of the background paper, loosely structured round four main features in the provision of teachers' professional development on a large scale: the content and aims,

1 Pre-secondary, primary and elementary are interchangeable terms used to denote classes and schools for students aged from5 to 12 or 13 years.

the structure and tools, scaling up and sustaining change, and evaluation. Section 7 presents the conclusions and recommendations agreed at the conference and through subsequent communication. It also suggests how the outcomes might be used by participants and others. An accompanying CD contains the papers written by participants from 15 of the 23 countries represented at the conference. A brief summary of this report is being prepared for wide circulation through the Academies.

1. Teaching and learning science through inquiry

1.1 What is IBSE?

Inquiry-based science education comprises experiences that enable students to develop understanding about the scientific aspects of the world around through the development and use inquiry skills. These skills are commonly taken to be those listed in Box 1.

Box 1

Inquiry …involves: making observations; posing questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyze, and interpret data; proposing answers, explanations, and predictions; and communicating the results. (NRC 1996: 23)

Some of these skills are generic and can be used in other subject domains as well as science, so it is important to recognise the nature of *scientific* inquiry if we are to avoid the misunderstanding of inquiry as a series of activities which may leave untouched students' conceptions about the phenomena being studied (Windschitl *et al* 2008). Clearly the subject matter is important, but even when the subject of study is a phenomenon or event in the natural or made world, the inquiry may not justify the label of 'scientific inquiry'. This may well be the case when, despite being active, the children are not developing ideas from evidence; there may be lots of action - observing and recording, even predicting - but not much use of the skills that engage their minds and develop their understanding. What is missing then is the scientific thinking that uses evidence to test ideas. These ideas may be initial, non-scientific ideas that children have developed from everyday experience, or the beginnings of theories that may eventually become 'big' ideas. This is the crucial element which distinguishes 'scientific inquiry' from inquiry in a more general sense.

There are two further points to make about inquiry. The first is that not all the skills will be used in every inquiry. First-hand manipulation of the materials or phenomena being studied is not always possible or appropriate. Understanding the apparent movements of the Sun, Moon and stars is an obvious example, but these can be studied by careful observation, the use of models and the interpretation of findings using different theories or ideas (IAP 2006). The second is that there are things to be learned - such as skills of using equipment and measuring instruments, conventions, symbols and names - that are best taught in other ways. So not all science learning involves inquiry, but it is essential where the aim is to develop understanding.

1.2 Why is IBSE important?

The answer to this question follows from a prior one: why is learning science important?
Reasons fall into three groups: value to the individual; value to society of it citizens being scientifically

literate; value to society in providing future scientists and technologists. For learners as individuals, science education helps them to understand aspects of the world around them, both the natural environment and that created through application of science. Not only does this serve to satisfy – and at the same time to stimulate – curiosity, but helps in their personal choices affecting their health and enjoyment of the environment as well as for their choice of career. There are equally benefits to society if individuals and groups make more informed choices in relation to avoiding, for instance, waste of energy and resources, pollution, and the consequences of poor diet, lack of exercise and use of drugs.

The understanding needed to achieve the first two of these benefits is not the specialised deep knowledge of the practising scientist or technologist but the grasp of some basic ideas of and about science, which are wrapped up in the concept of scientific literacy. In this context, 'literacy' means being able to engage effectively with different aspects of modern life, having the knowledge and skills that are needed by everyone, not just those who will be specialists, or make a career using knowledge, in some area of science. It requires a general understanding of the main or key ideas of science, of the nature and limitations of science, of the processes of science and the capacity to use these ideas in making decisions as an informed and concerned citizen.

Why and how learning through inquiry enables these values of science education to be realised follows from consideration of what students need to learn and how they learn.

What learning is important?

Current views of what students need to learn emphasise the importance of preparing them for an increasingly technological and scientific - and changing - world. Young people will have to make more choices than did those living in past decades. The ability to continue learning throughout life is acknowledged as essential for future generations and thus it has to be a feature in the education of every student. Developing this ability involves learning how to learn. By this is meant the achievement of various cognitive and affective outcomes indicating the skill, the will, the flexibility in thinking and the energy needed to make effective decisions. The ability to continue learning is recognised as needed by students in all countries, as underlined by the OECD:

> 'Students cannot learn in school everything they will need to know in adult life. What they must acquire is the prerequisites for successful learning in future life. These prerequisites are of both a cognitive and a motivational nature. Students must become able to organise and regulate their own learning, to learn independently and in groups, and to overcome difficulties in the learning process. This requires them to be aware of their own thinking processes and learning strategies and methods.' (OECD 1999: 9)

Furthermore there is widespread recognition of the importance of developing in children types of skill, attitudes, knowledge and understanding that are regarded as more important than accumulating large amounts of factual knowledge. Content knowledge can be found readily from the information sources widely available through the use of computers and especially the internet. What are needed are the skills to access these sources and the understanding to select what is relevant and to make sense of it.

The development of ideas

When students – or any learners - encounter a new phenomenon they use ideas from earlier related experience to propose a tentative explanation (hypothesis). There may be several ideas that come to mind and could provide an explanation. Some ideas may be eliminated through discussion with others who bring different previous experience to bear; other ideas will require new information to be sought in order to test their validity. An idea is tested by using it to make a prediction ('if this is the reason, then it follows that…'). New information can be sought in various ways, for instance though a practical investigation involving the manipulation of objects or through consulting appropriate sources such as books, people, the Internet and other reference material.

The new evidence may not agree with the prediction and so not support the initial hypothesis, in which case an alternative explanation needs to be sought. This is an important learning experience, since without the new evidence, learners would continue to think that their earlier ideas would apply. When new evidence does support the initial idea then that idea becomes strengthened because it then explains the new phenomenon as well as earlier experience. In this way ideas move from being 'small' (explaining just a particular event) to being 'bigger' since they explain a greater number of events. Understanding is built through this activity, which depends crucially on the inquiry skills used, on how predictions are made, what evidence is collected and how it is interpreted. Hence concepts and inquiry skills are essentially interdependent. Inquiry that does not lead to the development of science concepts - either because the content is not scientific or because only some of the skills are used - is not scientific inquiry and does not lead to development of scientific understanding.

1.3 Why start in the primary school?

The reasons for learning science and for changing the way it is taught leave open the question of why science education should start at the primary school. In contrast with the claims made for primary school science in the past, we now have research evidence for its significant role in the development of scientific understanding, enquiry skills and attitudes.

Developing scientific ideas

The evidence that children are arriving at their own ideas in the early years, whether or not there is science in the curriculum, is a powerful argument for ensuring that they explore and inquire in a way that promotes the development of reliable knowledge and basic science concepts. There is a considerable body of research evidence that shows that children develop ideas about the scientific aspects of the world around them whether or not they are taught science (Osborne and Freyberg 1985, SPACE 1990-98). Children's own ideas are often in conflict with scientific ones and, if taken into the secondary school, they can inhibit effective learning (Driver 1983). The conflict between children's own ideas and ones that they are taught in secondary education leads many to find science too hard, too confusing and too remote from their real experience.

A key aim of scientific literacy for all is the development of key 'big' ideas, meaning ones that are widely applicable and enable a grasp of situations where they apply. These 'big' ideas cannot be taught directly; they are necessarily highly abstract and indeed meaningless if they do not evoke the many real situations which they link together. For example, if children develop, through investigation and observation, an understanding that there is interdependence among plants and animals in their own environment - their back garden, the park, the stream or the hedgerow - they may eventually understand the reasons for protecting the rain forests. But if the big issues relating to conservation are the starting points, they may be understood at no greater depth than slogans and the relationships never more than superficially grasped. So the 'big' ideas (so called because they explain a range of related phenomena) have to be created from 'small' ones, developed through understanding specific events familiar to the children. The role of science at the primary level is therefore to lay a foundation of experiences and ideas about them that can later be built into the broader understandings denoting scientific literacy.

Developing inquiry skills

The importance of the development of the skills indicated in Box 1 follows from the way children develop understanding. When children are developing their ideas through their own thinking, the outcome will depend on the nature of the thinking. If the ways of thinking are non-scientific, then it can be expected that non-scientific ideas will be formed. Indeed this is the case when children bring to the classroom ideas formed as result of 'everyday' reasoning. When children observe events they may focus on certain aspects that confirm their ideas, leaving out of account evidence that might challenge them. They sometimes make 'predictions' that they already know to be true and so are not a test of an idea. In setting up a test they may not control variables that should be kept constant. In other words, the way in which these processes are carried out crucially influences the ideas that emerge.

Developing attitudes

Attitudes towards science form early and have already declined when children reach the end of primary school (Murphy and Beggs 2003). Some of this decline may be due to a general pattern for pupils' attitude towards most school subjects to become less positive with age (Tymms *et al* 2008) but it will also be due to their experience of science at school and influenced by myths and hearsay about science. To develop positive attitudes towards science, and scientific attitudes towards the use of evidence, it is important for pupils to experience scientific activity, to develop and use inquiry skills in answering some of their own questions about things around them (Rocard *et al* 2007). Through this essential starting experience they can begin to reflect on the questions that can and cannot be answered by scientific investigation and the kinds of conclusions that can and cannot be drawn from certain kinds of evidence.

1.4 IBSE in practice in the primary school

Implementing IBSE means that over a period of time, but not necessarily in each inquiry, students will be have the experiences and actions listed in Box 2 (taken from the IAP report of the working group on collaboration in the evaluation of IBSE). Individual items in the list are of little consequence alone; it is the combination of experiences relevant to a particular investigation that indicates learning through inquiry.

Box 2

Students' experiences indicating learning through inquiry

- Gathering evidence by observing real events or using other sources
- Pursuing questions which they have identified as their own even if introduced by the teacher
- Raising further questions which can lead to investigations
- Making predictions based on what they think or find out
- Talking to each other or to the teacher about what they are observing or investigating
- Expressing themselves using appropriate scientific terms and representations with understanding both in writing and talk
- Suggesting ways of testing their own or others' ideas to see if there is evidence to support these ideas
- Taking part in planning investigations with appropriate controls to answer specific questions
- Using measuring instruments and other equipment appropriately and with confidence
- Attempting to solve problems for themselves
- Using a variety of sources of information for facts that they need for their investigation
- Assessing the validity and usefulness of different ideas in relation to evidence
- Considering ideas other than their own
- Reflecting self-critically about the processes and outcomes of their inquiry.

(IAP 2006: 26)

Providing these experiences for students will involve teachers in the actions set out in Box 3 (from the same source as Box 2).

Box 3

Teachers' actions indicating inquiry-based teaching

- Providing opportunity for students to encounter materials and phenomena to explore or investigate at first hand
- Arranging for discussion in small groups and in the whole class about procedures that are planned or have been used, to identify alternatives and ways in which the approach to particular investigations might be improved
- Encouraging tolerance, mutual respect and objectivity in class discussion
- Providing access to alternative procedures and ideas through discussion, reference to books, resources such as the Internet and other sources of help
- Setting challenging tasks whilst providing support (scaffolding) so that students can experience operating at a more advanced level
- Teaching the techniques needed for advancing skills, including the safe use of equipment, measuring instruments and conventional symbols
- Encouraging students through comment and questioning to check that their ideas are consistent with the evidence available
- Helping students to record their observations and other information in ways that support systematic working and review
- Encouraging critical reflection on how they have learned and how this can be applied in future learning
- Using questioning to encourage the use of inquiry skills.

(IAP 2006: 26)

1.5 Obstacles to inquiry-based teaching

There is a growing body of research evidence to support the claims about the value of inquiry-based learning and international agreement as to its importance from organisations such as the OECD, IAP, European Commission, NRC. A synthesis of research on the impact of IBSE on students' learning outcomes, carried out by a team at EDC, found that a majority of relevant studies reported a positive impact (personal communication). Change to inquiry-based pedagogy is therefore firmly warranted and is being attempted in over 30 countries (IAP 2006). So why do we find children learning in a much more passive way and teachers frustrated by circumstances that prevent them teaching in the way many know would better serve children's scientific development and which they would prefer?

Surveys of teachers have been conducted in many different countries to reveal primary teachers' perceptions of the obstacles to teaching science through inquiry and investigations. They consistently find the main factors to be:

- Teachers' confidence in their grasp of the subject-matter
- External tests that require only factual knowledge
- Inadequate space and resources
- Shortage of time
- An over-crowded curriculum
- Large classes
- Lack of teaching assistants

In addition to these difficulties perceived by teachers there are other problems in teaching science at the primary level that are reported by researchers, observers, inspectors and advisers who visit schools and observe classroom practices. The problems they report include lack of progression in the development of ideas and skills, insufficient links between science and other subjects and children's tasks not taking account of their prior experiences. Evaluations have also reported children not being sufficiently challenged and teachers too willing to accept all ideas from children without comment or request for supporting evidence (eg ECBI evaluation, forthcoming).

There is a striking recurrence of these problems in all countries. Wherever teachers are expected to teach all subjects, many feel the need for resources and support in the classroom if they are to do more than give text-based instruction. Wherever there are high stakes tests, there is direct teaching to the content of what is tested and inquiry-based teaching is rare. Wherever teachers have large classes they may be overwhelmed by the difficulties of managing practical work and resort to whole class teaching. Wherever teachers lack a personal understanding of inquiry they focus on the 'doing' rather than the thinking that is needed to develop understanding. These problems combine to reduce science teaching to transmission of information, perhaps with the occasional demonstration, but essentially putting children in the role of passive receivers and not active agents in their learning.

What can be done?

There are massive implications in this situation for teacher education, for curriculum renewal, for development and supply of written and other resources, for the exploitation of ICT and informal learning opportunities and, of course, for professional development (PD) of teachers. These implications present great challenges for all involved in the improvement of science education. The focus of this report is just one of these challenges, the professional development of teachers, chosen because evaluations of IBSE implementation and other research outcomes have pointed to the teacher as being the single most important factor affecting student achievement (Hattie 2003). The concern is with teachers continuing to learn beyond their initial training. Whilst there is a good deal in common between the issues and approaches in initial teacher education and in-service education – and many science educators provide both – we deal only with the particular needs of teachers and others implementing IBSE in pre-secondary schools.

The next sections present the issues relating to PD that were discussed at an international conference held in October 2008 in Santiago, Chile, and the conclusions and recommendations that were reached. An accompanying CD contains the reports of relevant PD activities from some of the 23 countries represented at the conference.

2. Changing teaching through professional development

2.1 The need for continuing professional learning

The goals of modern education and of inquiry-based education in particular, require students to become more independent learners. This means teachers developing new relationships with students and having the confidence to allow students to develop their own ideas. Confidence and understanding play a large part in determining whether teachers provide students with the experiences that enable them to develop understanding of the world around them through inquiry. Teachers used to teaching science by giving information from a text book need the chance to experience, understand and value inquiry-based learning if they are to develop the confidence and skills to implement new programs effectively.

Change in teachers' understanding of what is involved in helping students to learn through inquiry has implications for how professional development (PD) is conducted. It takes time and effort for existing practices to be either replaced or modified and, unless underpinned by understanding and conviction of the value of new practices, it is all too easy for them to be implemented only superficially and soon fade away. Hence we must aim for teacher learning and commitment to continued learning. Although the fundamental changes often required may be better described as professional learning, we use the more familiar term to avoid confusion.

Practising teachers continue to learn in a variety of ways, ranging from informal contacts with other teachers to formal courses that lead to enhanced qualifications. For example, they may learn:

- from their own practice through action research conducted individually or with colleagues;
- through mentoring by a more experienced colleague or adviser;
- through in-school formal or informal in-service sessions;
- through formal professional learning courses in groups;
- from giving and receiving information about practice at conferences and inter-school in-service meetings;
- from researchers and teacher educators in courses focused on particular issues or changes (Bransford *et al.* 1999);
- from courses presented partially or wholly on-line (Harlen and Doubler 2004, 2007).

Their learning may be for personal and professional satisfaction or higher qualifications, but frequently is part of planned changes across whole schools, all schools in a region or whole national systems. How such large-scale changes can be brought about has been the subject of much research and theory (Fullan 2007). Experience shows that a variety of PD activities is more effective than depending on workshops and courses only, as reflected in the *Standards for Professional Development for Teachers of Science* (NRC 1996b). The examples of current practice in many countries (see CD) frequently include workshops, individual and supported work in the classroom, visits by trainers and visits to other teachers as well as developing and trialling new modules.

2.2 Stages in implementing change

Change in teachers' understanding and practice can take place to varying degrees. It has long been recognised that, in the case of curriculum change, the extent of implementation can be at different levels. Rudduck and Kelly (1976), studying the implementation of new curriculum materials in the early 1970s, identified a dimension reaching from 'awareness' to 'commitment'. At the 'awareness' end are teachers who know about the new materials but have yet to adopt their use. At the 'commitment' end are those who have become convinced of the value of the new materials and fully understand their rationale. In between these are teachers who use the new materials, at first somewhat mechanically and then with growing understanding of their purpose. A similar range of degrees of change exists in relation to pedagogical and assessment practices. Here too, effective implementation may involve giving up existing practices and a change in the role of the teacher; change which requires commitment supported by thorough understanding.

A widely validated sequence of stages in implementation was developed by Hall and Loucks (1977) based on the concerns that teachers have in implementing reforms. Hord *et al.* (1987) used this as a basis for the following series of stages:

Awareness	Little concern about or involvement in the reform
Informational	General awareness of the reform
Personal	Uncertainty about the demands of the reform and personal adequacy to meet those demands
Management	Concern focused upon efficiency, organizing, managing demands
Consequence	Focused upon impact of reform on students
Collaboration	Coordination and collaboration with others in using the reform
Refocusing	Exploration of possibility of major changes and alternatives

More recently, Holmes *et al.* (2007) have also placed awareness at the base of a model of professional learning, indicating that teachers must know enough about the context and purpose of change to be able to evaluate their own needs and hopefully to become willing to adopt new practices. Beyond awareness, the teacher's values and views of the usefulness of the change lead to grasping the opportunity for professional learning and subsequently to full engagement with new strategies and interactions.

Underlying these dimensions is the notion of progress in teachers from being 'novices' in the implementation of new programmes or pedagogy to becoming more 'competent' and eventually 'expert'. The characteristic differences between the novice and the expert across different field of activity are described by Bransford *et al.* (1999) primarily in terms of ability to see patterns and to identify the principles that apply. In the case of teachers, experts have a clear idea of how to help students learn and consistently use appropriate strategies based on the information they constantly gather about their students' learning. Novices, on the other hand, are concerned with the specific techniques rather than the big picture and with their own role rather than that of their students. 'Competent' teachers have progressed beyond novice status but not reached that of expert. They are more independent in choosing teaching strategies and more aware of how their students respond than novices but have not acquired the overview of teaching and learning of experts. The development of teachers from novice to expert is not necessarily a function of experience or years as a teacher. When new demands are made in adopting an IBSE programme, all teachers are likely to begin as novices and progress at different rates towards competence and expertise.

2.3. The challenge of IBSE

The practice of IBSE demands skills that differ considerably from those of traditional science teaching and assessment. For example, Crawford (2000) found from observing teachers that inquiry-based teaching requires teachers to take on a range of active and complex roles compared with traditional teaching. Shavelson (2006: 64)), citing the research of Furtak (2006), notes that 'it may not be sufficient for teachers to acquire the skills of inquiry; without the beliefs, the skills fall short of full implementation'. Teachers are unlikely to develop these roles, beliefs and new practices through informal teacher learning routes; rather they require some structured opportunities to consider examples and approaches to change. This does not necessarily mean that the approach is 'top down' nor that there is a recipe that teachers can be trained to follow. What it does mean is that teachers understand the reasons for changes and are active in seeing how to implement them in their own particular working environment. This parallels the active role that students have in learning with understanding.

The list of teachers' actions involved in inquiry teaching (Box 3) illustrates the changes that are likely to be required in classroom practice for those used only to teaching science, if at all, through a traditional, text-book based approach. The challenge is only intensified by the realisation that, although the items in this list refer to pedagogy, teachers also need a good grasp of the scientific content to be taught and of the nature of science. In almost all countries primary teachers feel less confident about teaching science than mathematics and language. Research (Murphy *et al.* 2007) shows that a poor background in science is largely seen as the cause of this lack of confidence. There is also evidence (Harlen *et al.* 1995; Harlen 1997) that teachers who lacked confidence tended to use teaching methods that confine students' activities to ones that are 'safe' and often impoverish students' learning opportunities. The strategies they adopted include relying heavily on a text book, work book or work cards with step-by-step instructions, emphasising expository teaching, underplaying questioning and discussion, and avoiding using any equipment that might 'go wrong'. On the positive side, however, Harlen *et al* (1995) reported that, given opportunity (which they may not have had at all in their own education), many primary teachers could develop some 'big ideas' in science with relative ease.

An even greater challenge can be to develop understanding of the nature of science and of scientific activity. To teach science effectively a teacher needs a clear notion of the nature of the subject - of the distinctive qualities that separate science from other subject domains. With such an understanding science can be taught as part of a topic, integrated with other subjects yet still retain its special features. Without such understanding there may be little activity, even in separate science lessons, that is truly scientific. The report of the IAP Working Group on Evaluation of IBSE Programs describes science as multifaceted, the important facets being that it involves

- developing knowledge and understanding about the natural world;
- observing, questioning, experimenting and attitudes that question rather than accept explanations of phenomena in the world around;
- logical reasoning about evidence combined with creativity and imagination;
- recognising that scientific theories and concepts of both individual learners and scientists, change as new evidence is uncovered.

In the next sections we discuss what is known from theory and practice about how to design, implement and evaluate PD programmes. The decisions about approaches to be taken are considered under four headings, which were used to structure and report the group discussions at the conference:

• *Content and aims* – e.g. topics covered in the PD; the aims of the PD activities; the view of student and teacher learning that underpins the PD activities.

• *Structure and tools* – e.g. how the PD activities are organised (duration and frequency of sessions, numbers involved); where they take place; training and other resources used; use of the internet or other ICT.

• *Scaling and sustaining* – e.g. how PD is made available to a large number of teachers; who other than teachers are involved (school principals, for advisers or inspectors, others); who provides the PD (the programme developers, university teachers, local advisers, specially trained teachers, others); how the providers themselves are trained; any permanent structures that make PD available on a continuing basis.

• *Evaluation* – e.g. what and how evidence has been collected about the PD activities and used to improve them (formative evaluation); what and how evidence been collected as to the effectiveness of the PD activities (summative evaluation).

These are not entirely separable aspects of PD provision; for instance, some approaches are less 'scaleable' than others, and tools are connected with content. However it is worth considering what experience shows to be necessary in terms of content to bring about genuine professional learning before discussing the problems of organisation, dissemination and evaluation.

3. Content and aims of professional development

Among the keyissues for consideration in relation to content and aims are the relative emphasis placed on

- increasing teachers' content knowledge and developing IBSE pedagogy;
- opportunities for 'learning through inquiry' and 'learning about inquiry';
- techniques and principles of new approaches (knowing how and knowing why);
- the formative use of assessment as part of teaching.

3.1 Developing teachers' scientific knowledge

A key question to be addressed in designing the content of a PD programme in IBSE is what attention is to be given to developing teachers' own knowledge of science and to developing their pedagogical skills. Most primary teachers feel insecure about their understanding of science concepts and consequently lack confidence in teaching. This often arises through assuming that teaching science is about transmitting facts correctly to students. There is no denying that primary teachers need to understand the science, but it is equally important for them to be able to engage students in learning in a way that develops their inquiry skills as well as their scientific ideas. The focus of PD in IBSE is on the pedagogical approach that develops scientific understanding through inquiry and this applies to teachers' understanding of science as much as to the learning of students. Thus part of the PD programme should engage teachers in learning science through inquiry at their own level, giving them first hand experience of using inquiry skills as well as understanding of the phenomena they study.

It is not possible to cover all concepts in this way, of course, and so there should be other sources of background information for teachers to use. In some cases the scientific ideas are explained to teachers as they work through a module of work for students. In other cases teachers' guides have sections on the background science. Scientists can help, too, as in France where a partnership between scientists (many being university students) and primary school teachers has been established over the last 15 years. The collaboration (ASTEP, 2008) can take several forms including support in the classroom or at a distance through e-mail or in the context of PD events. The Latin American website *Indagala*, derived from the French *La main à la pâte* web-site, enables teachers in Colombia to put questions to scientific experts and to communicate with other teachers (see CD). The account of work in Colombia also points out that since the inquiry modules are based on well-researched and tested material *(Insights)*, the focus of the PD can be on matters of how teachers use the materials and adapt them to the local context.

But however knowledgeable teachers are there will always be questions from children that they cannot answer – and indeed some that they should not attempt to answer if children can find the answer for themselves. Anxiety that children may ask difficult questions leads many teachers to organise the children's work so that opportunities for asking questions are minimised. This is to be avoided since questioning has a very important role in children's learning, particularly when they are encouraged to do their own reasoning. So it is important that teachers are prepared with strategies for handling children's questions. 'Handling' is not the same as answering; it means responding according to the kind of question being asked and trying to turn their questions into ones that they can investigate for themselves where possible. Teachers should also realise that not being able to answer a question immediately and having to ask an expert or consult another source is useful learning for students.

3.2 Learning through or about inquiry

A second key decision in planning PD activities can be expressed in terms of facilitating 'learning *through* inquiry' or 'learning about inquiry'. Learning through inquiry means that teachers experience inquiry at first hand. Teachers can be helped to develop understanding of science inquiry through participation in scientific activity. It requires that some time is spent giving them opportunity to question and investigate something quite simple in their everyday lives (such as why paper towels are made up of several layers; why ice floats; why the outside of a can of drink becomes moist when it is taken out of a fridge). These are not activities for students, and teachers are not asked to play a role, but to become investigators of these common phenomena. Reflection on what they understand initially, what more they find out, and how, can lead them to an insight into how science works. This approach is embodied in a 'workshop approach' described in Box 4.

Box 4

'A workshop is merely a shorthand way of indicating a learning experience in which the learner creates meaning or understanding through his or her own mental and physical activity….

For teachers to understand fully the meaning of active learning [IBSE] it is important for them to have experienced it for themselves and so this is one reason for advocating a large element of workshop activity in a teacher-education course. To help children learn in this way it is necessary to understand, not just at an intellectual level, but in terms of practice, what it means to carry out observation, to hypothesize, to make prediction, to plan an investigation, and so on. This is a tall order for those who may never in their own education have had opportunity to create and test a hypothesis based on their own ideas.

Further, not only do teachers and intending teachers need to experience these things for themselves, but to do so in a context where discussion can turn to analysing the role of process [inquiry] skills and concepts in their learning, to reflecting on the sorts of activities which encourage use of these skills and concepts, to considering the teacher's role in these activities and to identifying the range of class organizations, strategies and resources which are required.

This way of learning does not have to be restricted to developing personal knowledge of science. It can and should be applied to all the learning experiences in a teacher-education course. It means starting from the ideas which are already present and working with the learner, making use of evidence (from previous experience and logical arguments as well as direct observation, since we are dealing with adults) to change them. Working in this way has a double benefit in bringing about understanding in relation to the nature of learning and at the same time being the most effective way for teachers to learning the skills and abilities required for effective science teaching.' (UNESCO, 1992: 13)

By contrast learning *about* inquiry refers to having inquiry explained and described but not experienced. An important consideration in deciding this issue is the message about learning that is conveyed in the mode of engagement. Not only will teachers understand inquiry better through experiencing it but the mode of learning of the teachers should be consistent with the intended mode of learning in the classroom; otherwise inconsistent messages are communicated. *If teachers only follow instructions in their training, it is not surprising if they then teach their students only to follow instructions, with the result of inhibiting real inquiry.*

3.3 Starting from principles or techniques

A closely related decision concerns whether teachers are introduced to the rationale and principles of IBSE or are provided with techniques for putting a particular IBSE programme into practice.

Starting from principles requires teachers to be involved in working out how to make the changes in classroom practice that are needed to implement IBSE. As with all learners, what they have worked out for themselves is thoroughly understood and teachers will appreciate the reasons for taking certain actions. However, this approach is very demanding of resources, particularly time, and is not easily extended to large numbers of teachers.

Starting from techniques enables teachers to follow specific guidance in using new materials. Putting techniques into practice will give them experience of how their students respond when given the opportunity for inquiry. However, if teachers do not understand the reason for making changes in their practice they are likely to follow techniques mechanically. This leaves teachers unprepared for unexpected events and, being unable to deal with them, they are likely to resort to earlier practices and new ones will fade away. In order to make good decisions about when and how to use the techniques an understanding of their purposes in relation to underlying principles is necessary.

There are approaches that lie between these two, for instance where teachers are provided with some techniques which they are encouraged to try out and to modify in the light of the aims of IBSE. The changes might include, for example: their questioning style so that they ask more open questions that require thoughtful answers rather than the recall of information; arranging the classroom so that students can work in groups; enabling students to plan investigations; ensuring that students know the goals of their work and begin to recognise when they are learning and how they are learning. They would be encouraged to try these out and modify them to suit the contexts of their own classrooms. These are matters relating to pedagogy which can be changed even if teachers do not have new classroom materials such as work books and teachers' guides. If new materials are available then these, too, are considered as approaches to try, evaluate and modify. It would be important to ensure that these experiences lead to reflection on IBSE in action and so to understanding the reasons for adopting new teaching strategies.

Ideally we would like teachers to develop understanding of why IBSE is an effective way of learning science. How far a programme of PD leads to understanding of the principles behind the new practices may depend on several cross-cutting variables. One of these is the kind of rationale that is given for making the change. This can be highly pragmatic: 'because it works and leads to better learning'; or alternatively 'because this is *how* it works and leads to better learning'. The latter requires some understanding of how people learn whilst the former requires only evidence that learning is improved.

Other relevant variables affecting the approach that is most appropriate and feasible in a certain context include:

- the extent of the implementation (a few schools, a region, or nation-wide?)
- the content focus (how novel is the intended change?)
- the target (individual teachers, groups or whole schools?)
- the timescale and time available for teachers to reflect and share
- the funds available.

Examples on the CD show that in many cases the first part of the PD programme is concerned with strategies needed to conduct IBSE, with attention turned later to principles, in-depth study of inquiry and of its rationale.

3.4 Formative assessment as part of IBSE

In addition to understanding the principles of IBSE, teachers need understanding of how students learn and develop ideas. As Duschl *et al* (2006) point out:

'To support student sense-making in instruction, teachers need to know how students think, have strategies for eliciting their thinking as it develops, and use their own knowledge flexibly in order to interpret and respond strategically to student thinking. Teacher professional development can serve as a context for helping them understand students' ideas about the subject matter to inform their thinking' (Duschl *et al.* 2006, Chapter 10: 13).

What are described here are also important elements of using assessment to help learning. The formative use of assessment is a continuing cyclic process in which information about students' ideas and skills informs on-going teaching and helps learners' active engagement in learning. It involves the collection of evidence about learning as it takes place, the interpretation of that evidence in terms of progress towards the goals of the work, the identification of appropriate next steps and decisions about how to take them. It helps to ensure that there is progression and regulates the teaching and learning processes to ensure learning with understanding, by providing feedback to both teacher and student.

Formative assessment is also central to enabling students to acquire ownership of their learning, one of the key aspects of IBSE (Crawford 2000). Ownership requires that students know the goals of their work and the quality criteria to be applied so that they can themselves assess where they are in relation to the goals. This puts them in a position to identify, with their teachers, the next steps in their learning and to take some responsibility for progress towards the goals. The role of teachers in using assessment in this way is not only to find out where students are in relation to the goals and to provide activities with the right amount of challenge to advance their existing ideas and skills, but to share the goals with students and help them assess their own progress towards them. This role is also required of the teacher in IBSE.

Research on how to develop the use of assessment to help learning confirms conclusions about the close relationship between the formative use of assessment and inquiry. It also has implications for professional development. For example, James and Pedder (2006) concluded that:

(i) the effective promotion of assessment for learning in classrooms requires a radical transformation of both teachers and learning roles:
(ii) this requires considerable innovation in teachers' practices;
(iii) teachers need to learn these new practices;
(iv) this in turn, needs to be encouraged by a supportive culture for continuous professional learning that give teachers permission and opportunity to develop critically reflective modes of participation, for themselves and for their students.(James and Pedder 2006: 30)

In essence, inquiry teaching *requires* the formative use of assessment; both aim to develop learning with understanding and understanding of learning. A key component of PD experiences is, then, to enable teachers to use assessment to support active learning, ensure progress in learning and encourage students to take responsibility for identifying what they need to do to achieve the goals of their activities. Using assessment in this way requires that both teacher and students are clear about the goals of learning; a matter of some concern when, as often happens, teachers are focused on what students are doing rather than what they are learning.

4. Structure and tools of professional development

In relation to this aspect of PD some key issues concern

- the organisation and duration
- opportunities to learn with others
- materials for PD providers

4.1 Organisation and duration

Teachers have more chance of developing ownership of their learning when professional development sessions take place intermittently over a period of time, with opportunities for teachers to practise what they have learned in their own classrooms and to share experiences with others between sessions. Current practice in a range of projects aimed at changing pedagogy suggests that providing professional development in this way is more effective than concentrating the activities in a short space of time. For example, Black et al (2003) worked with teachers on the implementation of formative assessment in an extended programme over a period of 18 months. During this time the team and teachers met on 12 occasions for formal inputs and discussions. In between sessions teachers worked on the ideas in their classrooms, and were visited by team members. In such an extended programme teachers try out and modify what they learn and develop ownership over the new practices. They then share with others, learning from different experiences, so that what might start as transmission of new ideas from providers to teachers becomes the transformation by the teachers of their practices. This model makes provision for some factors in teachers' experience that have been found to have most impact on classroom practice, including opportunities to learn from and with other teachers, in their own or other schools, and collaborative inquiry into how problems in making improvements can be overcome (DfES 2001).

Although the continuing nature of professional development is generally emphasised (and for that reason is often referred to as CPD), there is always interest in the minimum time for PD that is likely to lead to change in practice. An important and extensive study by Supovitz and Turner (2000) is often quoted in this regard. The study was of the local systemic change initiative in 24 projects across the United States, information being collected by questionnaires from teachers and principals (787 schools and 4903 teachers). From their results the researchers concluded that 'it was only after approximately 80 hours of professional development that teachers reported using inquiry-based teaching practices significantly more frequently … than the average teacher' (p 973). Their conclusions were that there was 'a strong and significant relationship between professional development and teachers' practices and classroom cultures' (p 975), but the duration of most PD was too short to be effective. Their study also drew attention to other factors influencing change. For example, teachers from schools with low socio-economic status students used more traditional teaching methods than those with students of higher SES backgrounds. Another key influence was the supportiveness of the school principal.

4.2 Creating learning communities

Current views of how learning takes place, whether by young children or by adults stress the role of communication with others in the development of understanding. There is emphasis on communication through language, on the influences of cultural factors and on participation in a community of learners. Communication of ideas from direct experience requires learners to try to convey meaning to others and through interaction leads them to reformulating ideas in response to the meaning that others give to their experiences. The role of teachers in facilitating the kind of dialogue that promotes thinking has been described as 'dialogic teaching' which aims to 'harness the power of talk to stimulate and extend children's thinking' (Alexander 2004:1). The learning of teachers is similarly seen as brought about through collaborative interaction with others (Lave and Wenger 1991). Applied to PD in IBSE it means teachers finding the best way to achieve the aims of IBSE in their own classrooms through peer evaluation and sharing experiences. These experiences are emphasised in accounts of PD programmes in several countries, especially Iran, Colombia and Mexico (see CD).

Learning from others

Practical approaches involve groups of schools working together with the help of researchers, scientists and advisers from universities to turn ideas into classroom strategies that achieve the goals of inquiry-based teaching, taking account of the particular culture and environment of the school. Descriptions of new practices and how they were brought about have an important part to play. Case studies which describe how particular schools or school districts have managed the process of implementation and overcome problems are particularly useful, and need not be only in the form of written accounts. How a school with a poor supply of equipment and materials for investigative work has managed to mobilise parents to supply, and in some cases to make, simple containers and equipment for measuring, observing, and growing things, can inspire others with similar constraints. School managers can also learn from others' experience of how to make time available for teachers to meet to plan lessons and reflect on them. At the classroom level, accounts of how teachers have handled activities which require close supervision of group work can help others to avoid becoming overwhelmed by demands for help during these activities. Similarly, ways of catering for a range of ability within a class are particularly valuable to teachers to avoid the disruption that can follow from boredom or frustration. The act of describing the process of change in a school or class is useful in itself as well as enabling teachers to learn from the practice of others.

Examples of collaboration in improving practice

An example of development of inquiry-based science through a community approach is the EU-funded Pollen project (Pollen 2006a). This encourages the involvement not only of several schools in a city, but the communities surrounding the schools, too, through deliberate attempts to show to the public what the students are doing and to encourage interaction through exhibitions, visits (of people from industry and the community to schools and of schools to industry and community projects). The collaboration goes wider, extending across 12 cities in Europe each focusing on a particular area of potential problems in developing inquiry-based science, such as gender issues, transition from primary to secondary school, promoting citizenship values. Experiences are shared through a website which provides guides for teachers and trainers, materials and activities, and evaluation instruments, including attitude questionnaires for students. Pollen has also provided cases studies of varying length – some short and focusing on a single aspect of classroom practice and some giving the aims and activities of PD training (Pollen 2006b).

Another example from Europe concerned with policy-related matters in professional development is Peer Learning Activity (PLA). Through sharing experience in developing schools as learning communities, a group of 10 countries in the EU identified the transformation of schools into such communities as having a positive impact on students' achievement, teachers' motivation, retention and the implementation of change at the school level. The report of a second PLA taking place in the Netherlands in 2006 identified the conditions important for creating communities (see Box 5).

Box 5

Conditions for creating learning communities

• the ministry needs to have a clear vision of how it sees schools developing and the importance it attaches to teachers developing their skills and competences. This vision should be shared with and understood by all the schools' stakeholders, such as school principals and teachers, inspectors and education officials, who share responsibility for developing and communicating this vision;

• learning communities develop best when there are *systematic* opportunities for teachers to develop and learn. One-off activities have their place in tackling specific problems or issues but they are unlikely to lead to the development of a culture of learning;

• it is important to recognise that changing school cultures and systems takes *time*; consequently there is a need to *build capacity* systematically in the system rather than assuming that everything can be achieved easily and quickly; e.g. setting out a three or five year plan for teachers' continuing professional development which is linked to the school's objectives;

• teachers, like many of their students, are more likely to succeed and change practice when their learning is a *co-operative* endeavour, and their learning takes place in teams;

• teachers should be presented with clear *reasons* and sufficient *motivation* for developing and improving their practice. If teachers are not helped to develop an intrinsic motivation to change, it is difficult to create schools as learning communities;

• at the school level teachers are more likely to change through working together with their colleagues than from external 'experts';

• school leaders and education department officials should emphasise that learning communities are about teachers gaining *access to learning* and personal development. This approach is more likely to succeed in motivating teachers than focusing on improving their teaching

• *peer support* activities such as coaching and mentoring are particularly effective methods of helping teachers to develop; e.g. new school leaders can be assigned an experienced head teacher to provide guidance, and trainee teachers and newly qualified teachers can work with experienced subject-based mentors;

• creating an environment of *trust*, which allows school leaders and teachers to be confident that mistakes are part of the learning process, encourages more risk-taking and therefore more innovative approaches;

• at school level there is a need to offer structured *support* to individual teachers and school leaders. Providing 'scaffolding' which supports individuals' learning and further development creates the environment in which teachers can build on their earlier successes;

• it is crucial to provide adequate *support* and training for the school leadership team (and not only head teachers);

• training schemes (whether national or school-based) which are based on an assumption that each teacher wishes to learn in the same way and learn the same thing are likely to be less successful than schemes which recognise that teachers have *different* developmental needs at different times;

• change is more successful and long lasting if it recognises the value of *flexibility* – schools and individuals are different and any national system should accommodate a wide range of approaches.

(Extracted from the report of the Peer Learning Activity – schools as learning communities for their teachers – held in The Hague, the Netherlands, 28 May to 1 June 2006

http://www.cilo.europeesplatform.nl/files/habermwhl_teachers.doc

Formative assessment used to help teachers' learning

It will also be necessary to consider the teachers' starting points and existing ideas about science and how to teach it, just as it is important for students' learning to start from what they already understand. Concrete examples and first hand experience are essential for teachers, too, for it is easy for words to be misunderstood even by the most experienced teachers.

Experience of professional development aimed at changing teaching underlines two further conditions that apply equally to students' learning. The first is the need for feedback. When teachers begin to make changes and enter what may be, for them, uncharted waters, they need some feedback that can tell whether they are navigating successfully. This can come either from their observation of the effects of their actions – responses of pupils that show that their actions are worthwhile and helpful to pupils' engagement in learning – or from PD developers who gather information about teachers' progress and use it formatively in the way that the teachers do in using assessment to help their pupils' learning. Teachers need to know what they are aiming for and have some way of judging how well they are doing. What this means is that PD providers should be using formative assessment to help teachers develop their practice and become responsible for their own continued learning.

The second is the need for teachers to have time to reflect and to incorporate new practices into their teaching. One of the most helpful ways to spend some of this time is in talking to others and sharing experiences. Those teachers who have opportunities to co-teach or to discuss their problems and solutions with their colleagues find this more useful than being given written materials. Such experiences, ought to be built into professional development schemes.

4.3 Materials for providers of PD and initial teacher education

In the accounts of PD activities in different countries (see CD) there are examples of how time is spent on different activities. Differences in the programmes and experiences provided for teachers who have been involved in IBSE projects for varying times and in the PD provided for school principals, classroom advisers (monitors) and others are also illustrated. However, there is infrequent reference to the production of programmes or modules specifically for training those beyond the project development team who will be needed to train teachers in order to achieve large scale implementation. Materials for PD providers to use, setting out the procedures and providing materials for discussion and trial by teachers, should themselves be the subject of trial and evaluation.

Several accounts refer to the importance of preparing for this extension by setting up centres in regions or provinces for local provision of PD. Where these local centres are in institutions providing initial teacher education there is the opportunity for teachers to be introduced to IBSE in their pre-service courses as well as for the PD of serving teachers. Project teams in several countries have collections, in some cases in multimedia databases, of videos, powerpoint presentations and other materials for training which can be used by local trainers. However, personnel in the local centres need to know how to use the materials, to be aware of the issues identified here, for instance, and to ensure that they are conveying the essence of IBSE in the training they provide for pre-service and in-service teachers. These matters are clearly linked to the decisions about scaling up, discussed in the next section.

5. Scaling and sustaining change

If an IBSE programme is to influence more than a few schools, and so remain of little consequence to the national picture, it must have the possibility not only of reaching most schools but of doing so in a way that ensures that changes will be sustained. The factors to be considered include:

- The tension between prescribing approaches to inquiry teaching (top-down) and enabling teachers to develop their ideas for implementing inquiry teaching (bottom-up).
- The emphasis during dissemination given to 'transmission' or 'transformation'
- How PD providers are recruited and trained

5.1 Reconciling top-down and bottom-up approaches

Beyond the development phase, when the aim is to reach large numbers of teachers the approaches to professional development must be scaleable. Experience in many areas of change in education, be it in the curriculum, pedagogy, assessment or school organisation and management, is that participation in developing new procedures or materials is a most effective way of encouraging commitment to change. There are examples of groups of teachers working together on their concerns about student learning and generating innovative approaches to teaching and learning by sharing practice with each other, as in the PEEL project begun in Australia in the 1980s (PEEL 2008, Erickson *et al*. 2005). There are also many examples of groups of teachers working with researchers or developers, often in the early stages of a new program, in a safe environment where they can be creative and experimental, learn from each other, combine ideas, and achieve ownership of the emerging practices. Add opportunities to reflect and develop understanding of principles underlying the change and this experience can be a most effective form of professional development.

The opportunities to involve teachers in this 'bottom-up' approach are clearly limited in large-scale dissemination efforts. However it does indicate the kinds of experiences that are likely to be effective in cases where change requires more than adopting new techniques. Although there is less opportunity in a large-scale operation for participation in genuine development, the PD experiences can still support the collaborative learning that enables teachers to adapt and implement new ideas in the context of their own school and classroom. For example, the opportunity for teachers to visit each others' classrooms or to show video-tapes of their teaching (Frederiksen and White 1994) has been found effective in enhancing teachers' learning and, with appropriate funding, can be built into professional development programmes (UNESCO 1985).

Policy change is inevitably a top-down process but the same top-down approach may not serve so well in relation to facilitating change in classroom practice. In small scale pilot work change may seem deceptively easy. However, to ignore the importance of the often enthusiastic engagement of teachers which makes the pilot development successful would be to underestimate the difficulty of reaching the same level of understanding and enthusiasm in a large number of teachers. Teachers 'being told' about an initiative, without experiencing the participation that was a feature of the pilot, are not likely to adopt the changes with the same commitment.

The role of the PD provider is central and is as yet at an early stage of development. PD procedures need to be flexible enough to enable teachers to develop some ownership of the classroom actions that emerge. But replication of the experience and excitement of development may be limited because the course of the PD activities has to be pre-planned. As noted in section 3.3, the nearest approach to reproducing the insights that come from genuine involvement in development is through experiences which start from the need for change and the rationale for IBSE, provide some strategies and examples, and encourage teachers to adapt them to their own work. Alternatives are to present teachers with more closely defined classroom techniques to be tried, adapted or to be followed according their particular starting points.

5.2 Transmission or transformation

Making changes in teaching and students' experience across a large number of schools requires opportunities for professional development to be made available on a greater scale than for earlier trials. As mentioned earlier, some approaches are more easily duplicated on a large scale than are others. Models of 'scaling up' can be divided into two groups which can be described as aiming primarily at transmission or alternatively at transformation.

Common among transmission models are various forms of cascading. This can take the form of 'training trainers', where one or more groups of professional developers are trained not only in the methods and materials involved in the change, but in how to present these to teachers. There may or may not be training materials to support the transfer of the message down from the developers to the schools. Where training materials exist the 'dilution' of the message as it is passed along from trainer to teacher is likely to be less than in the absence of a 'standard' training package. The use of illustrative material on CDRoms, or provided through the internet, is commonly part of such packages. These help to ensure that the message is transmitted more or less unaltered. At the same time, however, it is likely to mean that there may be less match to different needs.

Another form of cascading is through schools involved in trials being encouraged to spread the ideas to others in their schools and to neighbouring schools. This approach of 'teachers talking to teachers' carries conviction that the change is feasible and worthwhile in familiar school contexts. This form of 'spreading' is important within schools, to involve the whole school staff, where typically only one or two teachers have been involved in trials.

Other transmission models are market-driven, such as when publishers provide free training for new classroom materials, which schools are encouraged to purchase. Some publishers insist on teachers attending training in the use of new materials as a condition of purchase. However, these are likely to be only short, one-off, sessions which can go little further than providing familiarity with the content.

Transformation models (Senge and Scharmer 2001) acknowledge to a far greater extent than transmission models, the complexity of change and particularly the need to consider where teachers and schools begin. They blur the distinction between curriculum development, dissemination of new materials and pedagogy and professional development. To some extent they also challenge the view that bringing about change in teaching, or indeed other aspects of policy or practice in education, is a matter of 'roll out', or 'dissemination' or even 'scaling up', if by these terms is meant the reproduction in different contexts of processes more or less unaltered. Instead, transformation models emphasise learning at all stages of the process of change, not just at the trial stages, after which those outside the trials can be told what to do. For real change, it is argued, as with all learning, the individuals involved need to take more control of what they are being asked to do, to make sense of it through reflection, share it with others, until new ideas and processes become internalised. Ideas of engagement, of purposes, of collaboration, of manageability and of contextualisation are seen as central in order to avoid the adoption of actions and procedures that are separated from the ideas and purposes behind them.

5.3 Training of PD providers

The above discussion highlights the need for PD of teachers that gives them opportunities to develop a wide range of skills and capabilities including

• understanding and skills of IBSE pedagogy;

• background knowledge in science sufficient to create confidence;

• familiarity with new classroom activities and materials;

• personal understanding of the nature of science;

• ability to assess students' understanding and skills in science and to use this information to help students' learning.

In turn this requires expert PD providers. Clearly it is essential for those leading PD activities themselves to have the understanding and attitudes that are needed by teachers. In addition, they need to have the ability to educate adults. In the development phases of a new program the developers and researchers generally also lead the PD for teachers and others involved. This is not possible at the 'scaling up' stage when large numbers of PD courses are required. The essential role of the PD providers, as intermediaries between the project team and the teachers in large-scale implementation, needs to be considered in the plan for expansion of a program.

A common feature of the burgeoning development of IBSE projects is the involvement of university tutors in the stage of development of strategies, classroom activities and materials and in small scale pilot trials. Beyond this stage there is currently in many countries a general shortage of personnel with the necessary range of expertise to conduct PD in IBSE. Various actions are being undertaken to solve this problem, which threatens to prevent the change on the scale that is really needed for IBSE to make its contribution to widespread scientific literacy. The approach in Chile and Colombia, for example, is to build capacity by continuing the professional development of teachers so that some can advance from being 'competent' to being 'expert' (see Section 2.2) and can become PD providers within their school and neighbouring schools. Incentives to undertake the necessary training may include obtaining credits towards a master's degree at a university, as already in operation in Colombia. Associated with this is the proliferation of centres that have some autonomy so that not everything has to issue from the original centre of the development. These regional or district centres can act as foci of learning communities, for meetings and the distribution of materials and resources. As noted in Section 4.3, basing these in institutions for initial teacher education can be an important step to including IBSE in pre-service teacher training, which is clearly an element in embedding IBSE in practice nation-wide.

Other countries may follow the example of Mexico in developing 'on line' PD materials. When these on-line resources are designed for active and collaborative learning the advantages of group collaboration can be achieved without the difficulties that often accompany attending courses. For example, in an on-line inquiry-based science course for elementary teachers, participants in different parts of the country are arranged in groups who communicate with each other one-line. They work off-line conducting investigations and for reflection and then report to others on-line, reading and commenting on others' experience. A similar combination of on-line and off-line activities enables teachers to try out pedagogical strategies in their classrooms and share their experiences. A group tutor 'listens in' and intervenes only to encourage teachers to respond to and question each other (Harlen and Doubler 2004). Such experiences cannot wholly replace face-to-face interactions for teachers, but they may, if the technology is available, provide the additional experiences that are needed by PD providers.

6. Evaluation of professional development

The concern here is with the evaluation of the process and effectiveness of the PD provided for teachers. In deciding what and how relevant data are to be collected it is necessary to consider:

- the complexity of factors which influence change in pedagogy

- the purpose of the evaluation.

6.1 Factors influencing change in classroom practice

Professional development is one element in an IBSE programme, others being the classroom materials provided students, the teachers' guides, students' notebooks, etc. Thus it is difficult, if not impossible, to separate the effect on students of PD from that of these other elements of the programme and also from the influence of out of school experiences through the media and at home. Nevertheless PD is a major factor affecting teachers' pedagogy and, through this, the way in which students interact with the materials, their peers, the teacher and other adults in the classroom. Indeed teachers generally value opportunities for professional development and identify them as one of the key factors in improving students' learning (e.g. Wellcome Trust 2005), yet hard evidence linking the two is difficult to come by. In any innovation that impacts only indirectly on students there is a long chain of actions between the input and changes in students' achievement (Harlen, 2004). In the case of PD, for instance:

• However potentially sound the PD experience may be, a teacher may not engage fully with, or may misunderstand, some of the intended messages.

• Teachers fully understanding the techniques and reasons for new practice may be restricted in implementing change by school policies, such as timetabling, or district policies, such as requirements to prepare students for certain tests.

• The practices of other teachers who teach the class may conflict with what is required for inquiry-based learning; they may differ, for example, in the extent to which students are expected to collaborate and discuss their work with each other.

• Pressure from parents and the general public, who have certain expectations of what teachers should do, may favour traditional rather than new practices.

In addition, there are the effects of the teachers' own background, experience and beliefs, which will transform, perhaps unconsciously, the messages intended to be conveyed. Consequently there are too many variable influencing students' learning for this to be a useful measure of the effectiveness of teachers' PD. By the same arguments, it may not be valid, in the short-term, to evaluate the PD by the extent of change in observable classroom practice. Instead, it is more useful to find out whether or not relevant experiences are provided, and these might include advice on how to overcome some of the obstacles to change just listed.

6.2 Formative and summative purposes

As with all evaluations, there should be a clear purpose, which then determines the focus, criteria and methods used. The main purposes are formative – to improve the PD – and summative – to judge its effectiveness. Not many of the current IBSE programmes have reached the stage of collecting summative evaluation data about the success of the PD they provide, beyond the impressions of teachers involved. Indeed not many have collected systematic formative evaluation data about the process of PD that can be fed back into the design of the PD programme.

Evaluation of PD is complex, since most IBSE programmes include a range of provision such as workshops, help in planning lessons, classroom advisers (monitors), on-line and e-mail communication with science or pedagogical experts, peer- and self-assessment. It is also necessary to take into account the stage reached by teachers in the development of expertise in IBSE and the opportunities for teachers to put new teaching strategies into action. As noted in Section 6.1, there can be informed commitment to change as a result of PD, even though the particular constraints in which teachers work may mean that it will take time before all intended changes can be made. So, in considering the effectiveness of different approaches to PD we might, as initial evidence, take the degree of teachers' understanding and commitment to IBSE as an indication of 'success'.

For formative assessment, then, the questions to be addressed would such as:

– How does the PD enable teachers to develop their view of the nature of science and scientific activity?

– How are teachers helped to understand the meaning of inquiry in science education and how inquiry-based science teaching differs from text based teaching?

– What opportunities were there for teachers to a) try out inquiry-based activities extend b) understand the underlying principles c) apply them to other topics?

– To what extent are teachers helped to develop the practices listed in Box 3?

– Are PD experiences adapted to match the needs of teachers at different stages of competence in IBSE?

– .....

The Pollen project (2006b) provides suggestions for PD course evaluation in the form of questions to be answered by teachers. There are also checklists for trainers to use in discussing teaching plans which teachers may draw up as part of the PD activities. A more detailed tool intended both for use in observing lessons and in planning PD is provided by Zubrowski (2007).

When a PD programme has been established and widely used and teachers have opportunity to apply what they have learned, it may be appropriate ask questions for summative evaluation. However even in ideal circumstances any change in students' learning due to teachers' PD is bound to be small, because of the other influences on their learning. It is their experiences rather than their outcomes that indicate the effectiveness of the teacher and of the PD. Thus the focus should be on the classroom practice, the understanding, the opinions and values of the teacher, and the students' experiences of inquiry.

Summative evaluation questions are therefore, such as:

– What aspects of inquiry learning are and are not reflected in teachers' lesson plans, for instance, do teachers identify appropriate equipment, link the lesson to previous work and everyday life and students' ideas?

– In observed lessons, do teachers ask productive questions and listen to the answers, involve students in planning, in collecting evidence and in interpreting results?

– To what extent do students have the experiences listed in Box 2?

– Do students use inquiry skills to test and develop scientific ideas?

– How do the classroom practice of teachers who have experienced PD in IBSE compare with those without this experience?

– …

As with all evaluation in education it is important not to rush into asking summative questions too soon. The first time teachers try new approaches or materials they tend to follow them rigidly. Only when they become more familiar do they feel free to adapt and take more notice of their students' reactions rather than only their own actions. Mistakes in judgement of the impact of change can be made by not allowing time for teachers to try, reflect and become comfortable with new practices. It is important not to forget that IBSE requires for many a considerable shift in their view of the role of a teacher.

7. Conclusions and recommendations

The conclusions and recommendations agreed as a result of two and a half days of discussions at the International Conference on Teachers Professional Development in IBSE in the pre-secondary education are listed below. The group discussions focused in sequence on the four themes identified as relevant to the operation of professional development: content, tools and structure, scaling-up and sustaining change, and evaluation. Although overlapping, these themes provide a useful structure for reporting the conference outcomes. The inputs and discussion throughout the conference also served to confirm the aims of professional development in IBSE for pre-secondary school teachers.

It is the intention of the IAP that this report should not only provide a record of a conference but also be of use to participants and others in designing and evaluating the provision of PD in IBSE. The final section suggests possible ways of using the report.

7.1 Conclusions

Aims of professional development (PD) in IBSE at the pre-secondary level

Professional development programmes in IBSE should enable teachers to

• experience at their own level using inquiry skills and conducting different forms of inquiry;

• develop their own content knowledge through inquiry and through the use of resources;

• acquire a deep understanding of how learning takes place and of their role in students' learning through inquiry;

• be prepared to expect and to deal with the unexpected;

• know how to 'handle' children's questions and to be comfortable with not knowing the answers to all their questions;

• realise that teacher learning is a life-long process;

• develop skills of formative assessment including self-assessment by both students and teachers;

• assess and report students' progress in learning using a range of summative assessment methods.

Content of PD

The content of professional development programmes should

• provide a vision of effective inquiry in action through direct first-hand experience, cooperative group work and study of good examples;

• provide criteria for teachers to evaluate and advance their own progress in implementing IBSE;

• enable teachers to extend their content knowledge through access to written and on-line sources and to scientists;

• work within the mandatory curriculum and embed IBSE in the system;

• engage teachers in analyzing and criticizing examples of IBSE classroom materials;

• motivate teachers to change through supported (scaffolded) work in their classrooms as part of a PD program so that they can observe the impact on their own students.

• enable teachers to use the environment, to connect science to other subjects, to make activities relevant to children's lives and, as appropriate, to blend scientific knowledge with indigenous knowledge;

• challenge the belief of teachers that assessment of students is only summative and external and enable them to make their own assessment of students' progress in scientific skills, concepts and attitudes;

• be based on evidence of what works, where available, treating education as a science.

Structure and tools of professional development

Professional development in IBSE should

• use technology to provide examples and to support evaluation of teachers' practice;

• allow for the different starting points and initial beliefs of teachers as learners in IBSE practice and enable them to develop their practice together in learning communities;

• recognize and cater for the different stages in the development of expertise (novice, competent, expert) as teachers learn;

• move from a transmission approach, which may be a good starting approach in many cases, towards one aiming for transformation of teachers as they take ownership of the principles of IBSE;

• convey the value of active learning in the mode of interaction between people, and between people and materials during the PD experiences;

• involve scientists as well as experts in school education in the PD program; building bridges between the two communities and between schools and universities

• take advantage of the range of contexts in which teachers learn - formal and informal, inside and outside the classroom.

• where possible support additional informal learning through the internet and other media;

• build into PD experiences time for informal interaction among teachers;

• provide some peer (or monitor/advisor) support in the classroom, based on clearly defined roles for the teachers and supporter;

• encourage action research by teachers to develop confidence and understanding;

• model the use of notebooks by learners during PD;

• combine concentrated PD experience (e.g. of 2 or 3 consecutive days) with continuous shorter follow up experiences.

Scaling up and sustaining change

Procedures for large-scale dissemination and implementation should

• recognize the large amount time and resources needed for spreading change;

• proceed steadily ensuring sound implementation at each step;

• create from the originating centre local nuclei (universities, institutions) which then become centres for PD that can take local circumstances into account;

• identify exemplary operating centres to demonstrate effective scaling strategies;

• identify and work with the policy-makers who control the resources needed to provide PD;

• take active steps to communicate to the community and community leaders and to public and private funders of PD the importance of disseminating IBSE and the cost to society of not doing so;

• train trainers and provide some career paths and due rewards for trainers and those who support teachers in classrooms;

• provide trainers with good examples of PD in action with commentary on the rationale for the content, tools, etc;

• use information technology to provide access to PD and support for remote communities;

• involve the ministry of education, independent institutions (universities, the Academies) and industry in catering for continuing PD and support;

• ensure the involvement of universities or other institutions which train pre-secondary teachers courses, whilst recognizing that even those with IBSE in their pre-service education will need continuing PD

Evaluation

Evaluation of professional development courses should

• be based on a shared view of what it means to implement IBSE;

• be part of a program of evaluation that includes evaluation of classroom materials;

• be designed with a clear purpose in mind, which may be

o to justify resources and the funding used in providing PD,

o to improve the learning experiences of teachers (formative),

o to compare the effectiveness of different designs, approaches and components of PD in IBSE;

• aim to identify the experiences that teachers value and find most effective in their journey;

- include strategies for formative evaluation of the training;
- ensure that all the forms of PD that teachers experience are included: for instance
  - o formal courses,
  - o classroom support (from university, ministry personnel, other teachers),
  - o co-planning with peers or monitors/advisors,
  - o study of materials and examples (using technology),
  - o participation in the generation or adaptation of materials;
  - o participation in the design of strategies for formative and summative assessment;
- use change in teachers rather than in students as outcome measures/indicators eg the understanding of teachers, their reasons for specific actions in the classroom, their planning and actions;
- encourage associated research studies using more carefully defined samples to supplement the evaluation.

7.2 Recommendations

The group and plenary discussions of the conference identified a number of challenges for the IAP in the further development of IBSE and the role of teacher professional development in it. The following actions were recommended.

In relation to the importance of IBSE

1. The case for IBSE particularly at the pre-secondary school should continue to be made through:

   - short publications aimed at ministries of education identifying the benefits of IBSE and the disadvantages of not pursuing it throughout primary and secondary education;
   - emphasizing the international consensus on the importance of IBSE;
   - summarizing research on the outcomes of IBSE;
   - publication of reports of evaluations of IBSE programs;
   - the use of IT and the media to explain and show IBSE in practice.

In relation to the professional development of teachers

2. IAP should publish and distribute the information and findings in this report in several languages to all countries, including those without Academies.

3. The limited funds available to the IAP should be recognized and action taken to ensure the involvement of universities, ministries, funding agencies, professional associations and teachers' unions and other bodies with the potential to energize policy-makers in each country.

4. There should be international cooperation to develop and share:

- examples of PD programs in IBSE for pre-secondary school teachers;

- materials for teachers and for trainers that can be adapted to different contexts and IBSE programs;

- procedures, criteria and instruments for evaluation of PD.

5. International workshops for PD activities should be mounted to encourage a shared view of content and procedures.

6. The findings of evaluations of PD programs should be published and made widely available.

7. Associated research should include a review of research into teacher learning and studies aimed at identifying effective approaches to PD in IBSE for pre-secondary school teachers.

7.3 Some uses of this report

The brief rationale for IBSE in pre-secondary education given in the first section of this report makes a case for the focus here on professional development of teachers. Subsequent sections have underscored some key issues that have to be faced in designing programs of PD for IBSE. The discussion has included matters relating to: content and aims (how to balance the need to improve teachers' scientific knowledge with the importance of ensuring a thorough understanding of inquiry, what attention to give to theory and to formative assessment); structure and tools (how to organize sessions and create learning communities); scaling and sustaining change (how to balance dissemination of IBSE practice without too much change with the importance of teachers having ownership of the teaching strategies and freedom to adapt them to suit their context, and how to train trainers); evaluation (using evaluation to improve a PD program).

Through setting out some findings from practice and research it is hoped that those involved in designing, presenting and participating in PD programs will benefit from the experiences of others, avoid some pitfalls and make better decisions about what is most appropriate in their particular circumstances. This report is therefore of significance not only to policy makers and administrative personnel, but also to teacher education faculty, science education consultants, school principals and teachers.

The conclusions emerging from the conference embody standards that the participants considered should be reached by PD programs. 'Standards' here means expectations of quality – features of programs that are worthwhile aims. The extent to which a program meets these standards can be evaluated by turning each conclusion into a question to be addressed to the various features of the program. For instance:

> Does the content provide a vision of effective inquiry in action through direct first-hand cooperative group work and study of good examples?
>
> Does the content provide criteria for teachers to evaluate and advance their own progress in implementing IBSE?
>
> …….
>
> Does the program use technology to provide examples and to support evaluation of teachers' practice?
>
> Does the program allow for different starting points and initial beliefs of teachers as learners in IBSE practice and enable them to develop their practice together in learning communities?
>
> …….

Of course not all such questions will be relevant in a particular case but considering the whole set and selecting the most relevant is part of ensuring that all the key issues are considered in planning and evaluation. Neither are these questions ones to which a simple answer can be given; their role is to focus attention on features that experience shows to be important in effective PD programs and on the information required for evaluation.

References

Alexander, R. (2004) Towards Dialogic Teaching: Rethinking Classroom Talk. 2nd Edition. Cambridge: Dialogos.

ASTEP (2008) Supporting Teachers Through the Involvement of Scientists in Primary Education (ASTEP) Paris: Academies des Science.

Black, P., Harrison, C., Marshall, B. and Wiliam, D. (2003). Assessment for Learning: Putting it into Practice. Maidenhead: Open University Press.

Bransford, J., Brown, A. and Cocking, R. (Eds) How People Learn. Washington, D.C.: National Academy Press.

Crawford, B. (2000) Embracing the essence of inquiry: new roles for science teachers, Journal of Research in Science Teaching, 37 (9) 916-937.

DfES (Department for Education and Skills) (2001) Learning and Teaching – a Strategy for Professional Development. London: DfES.

Driver, R. (1983) The Pupil as Scientist? Milton Keyes: Open University Press.

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

Erickson, G., Brandes, G.M., Mitchell, I. and Mitchell, J. (2005) Collaborative teacher learning: Findings from two professional development projects, Teaching and Teacher Education, 21, 787-798.

Frederiksen, J. and White, B. (1994) Mental models and understanding: a problem for science education. In E. Scanlon and T. O'Shea (eds) New Directions in Educational Technology. New York: Springer-Verlag.

Fullan, M. (2007) The New Meaning of Change. 4th Edition. New York: Teachers College Press .

Furtak, E (2006) The problem with answers: an exploration of guided scientific inquiry, Issues and Trends, 453-467.

Hall, G.E. and Loucks, S.F. (1977) A developmental model for determining whether the treatment is actually implemented. American Educational Research Journal, 14 (3) 263 – 76).

Harlen, W. (2004) Evaluating Inquiry-Based Science Developments. Paper commissioned by National Research Council. May 2004 as background for a meeting on Evaluation of Inquiry-Based Science held in Washington DC.

Harlen, W. (1997) Primary teachers' understanding in science and its impact in the classroom, Research in Science Education, 27 (3): 323-337.

Harlen, W. and Doubler, S.J. (2007) Researching the impact of online professional development for teachers, in R. Andrews and C. Haythornthwaite (eds) The Sage Handbook of e-Learning Research, London: Sage, 466-486.

Harlen, W. and Doubler, S.J. (2004) Can teachers learn through enquiry on-line? Studying professional development in science delivered on –line and on-campus. International Journal of Science Education 26 (10) 1247-1267.

Harlen, W., Holroyd, C. and Byrne, M. (1995) Confidence and Understanding in Teaching Science and Technology in Primary Schools. Edinburgh: Scottish Council for Research in Education.

Hattie, J. (2003) Teachers makes a difference: what is the research evidence? Australian Council for Educational Research Annual Conference on Building Teacher Quality.

Holmes, B., Gardner, J. and Galanouli, D. (2007) Striking the right chord and sustaining successful professional development in information and communications technologies, Journal of In-Service Education, 33 (4), 389-404.

Hord, S.M., Huling-Austin, L., Hall, G.E., and Rutherford, W. (1987) Taking Charge of Change. Alexandria, VA: ASCD.

IAP (2006) Report of the Working Group on International Collaboration in the Evaluation of Inquiry-Based Science (IBSE) Programs. Santiago, Chile: Fundacion para Estudios Biomedicos Avanzados de la Facultad de Medicina.

James, M. and Pedder, D. (2006) Professional learning as a condition for assessment for learning, in J. Gardner (ed) Assessment and Learning. London: Sage.

Lave, J. and Wenger, E. (1991) Situated Learning: Legitimate Peripheral Participation. New York: Cambridge University Press.

Murphy, C., Neil, P. and Beggs, J. (2007) Primary science teacher confidence revisited: ten years on, Educational Research, 49 (4): 415-430.

Murphy, C. and Beggs, J. (2003) Pupils' attitudes towards school science, School Science Review, 84 (308): 109-116.

National Research Council (NRC) (1996) National Science Educational Standards. Washington DC: National Academy Press.

OECD (1999) Measuring Student Knowledge and Skills. OECD Programme for International Student Assessment (PISA). Paris: OECD.

OECD (2006) Assessing Scientific, Reading and Mathematical Literacy: A Framework for PISA 2006. Paris:OECD.

Osborne, J. and Dillon, J. (2008) Science Education in Europe: Critical Reflections. London: Nuffield Foundation **http://www.nuffieldfoundation.org/fileLibrary/pdfSci_Ed_in_Europe_Report_Final.pdf .**

Osborne, R. and Freyberg. P. (1985) Learning in Science: the Implications of 'Children's Science'. Auckland: Heinemann.

PEEL (Project for Enhancing Effective Learning) (2008). **www.peelweb.org**
Peer Learning Activities (PLA) (2006) Report of PLA, the Netherlands.
http://www.cilo.europeesplatform.nl/files/habermehl_teachers.doc

Pollen project (2006a) Seed Cities for Science. **www.pollen-europa.net**

Pollen project (2006b) Seed City Trainer. **www.pollen-europa.net**

Rocard, M. et al (2007) Science Education Now: A Renewed Pedagogy for the Future of Europe. Brussels: EC Directorate for Research (Science, Economy and Society).

Rudduck, J. and Kelly, P. (1976) The Dissemination of Curriculum Development: Current Trends. Slough: National Foundation for Educational Research.

Senge, P. and Scharmer, O. (2001) Community action research: learning as a community of practitioners, in P. Reason and H. Bradbury (eds) Handbook of Action Research: Participative Inquiry and Practice. London: Sage 238-49.

Shavelson, R.J. (2006) Research in conjunction with IBSE evaluations, Appendix D, Report of the Working Group on International Collaboration of Inquiry-Based Science Education Programs. InterAcademy Panel (IAP), published in Sanitago by the Fundacion para Estudios Biomedicos Avanzados de la Facultad de Medicina.

SPACE Reports (1990-1998) Titles include: Evaporation and condensation (1990), Light (1990) Growth (1990) Electricity (1991), Materials (1991), Processes of Life (1992), Rocks, soil and weather (1993), Earth in space (1996), Forces (1998). Liverpool: University of Liverpool Press.

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

Tymms, P., Bolden, D. and Merrell, C. (2008) Science in English Primary schools: trends in attainment, attitudes and approaches, Perspectives on Education 1 (Primary Science) **www.welcome.ac.uk/perspectives**

UNESCO (1992) Sourcebook for Science in the Primary School: A Workshop Approach to Teacher Education' by Harlen, W. and Elstgeest, J. Paris: UNESCO.

UNESCO (1985) The Training of Primary Science Educators – A Workshop Approach, Document Series No 13 W. Harlen (Ed). Paris: UNESCO available for download at **http://unesdoc.unesco.org/images/0006/000641/064166eb.pdf**

Wellcome Trust (2005) Primary Horizons: Starting out in Science. London: Wellcome Trust.

Windschitl, M. (2003) Inquiry projects in science teacher education: what can investigative experiences reveal about teacher thinking and eventual classroom practice? Science Teacher Education, 87, 112- 143

Zubrowski, B. (2007) An observational and planning tool for professional development in science education, Journal of Science Teacher Education, 18, 861-884.

Appendix A

Members of the IAP International Oversight and Global Activities Committees at the time of the conference

The conference planning was the work of the IAP International Oversight and Global Activities Committees. Members of these committees were as follows:

International Oversight Committee of the IAP's Project on the Evaluation of IBSE Programmes:

Wynne Harlen, Chair

Yves Quéré,

Jayashree Ramadas,

Senta Raizen

Dietrich Schiel

Members of the IAP Global Activities Committee

Jorge Allende, Chair

Wynne Harlen,

Pierre Léna,

Jose Lozano,

Jackie Olang,

Pat Rowell

Soon Ting Kueh

Appendix B

Draft programme for the conference on Professional Development for IBSE in pre-secondary education, October 20-22, 2008

	Day 1 (20 October)	Day 2 (21 October)	Day 3 (22 October)
9:00 am	Inaugural session Dr. Jorge Allende, Chilean Ministry of Education authorities, Chilean Academy of Sciences, José Lozano Coordinator IANAS Program	Chair: Ms Sally Shuler Plenary presentation Dr. Wei Yu (China)	Chair: Mr. Nicolas Poussielgue Plenary presentation Dr Rosa Deves, (Chile and Latin America)
9:45 am	Overview and presentation of issues from background paper Dr. Wynne Harlen	Plenary presentation Dr. Pierre Lena , France and the EU	Plenary presentation Dr. Hubert Dyasi (USA)
10:30 am - 11:00 am	*Coffee/tea break*	*Coffee/tea break extended to 11:30 for viewing posters*	*Coffee/tea break*
11:00 am	4 parallel group discussions ***Theme 1: Content and aims***	4 parallel group discussions ***Theme 3: Scaling up***	Summary and recomendations Closure: Dr. Jorge Allende
1:00 pm - 2:30 pm	*Lunch*	*Lunch*	
2:30 pm	4 parallel group discussions ***Theme 2: Tools***	4 parallel group discussions ***Theme 4: Evaluations***	
4:30 pm 5:00 pm	*Coffee/tea break*	*Coffee/tea break*	
5:00 pm	Plenary session: reports from discussion groups	Plenary session: reports from discussion groups	
5:45 pm	End of main sessions	End of main sessions	
6:00 pm	Meeting of GAC and reporters	Meeting of GAC and reporters	

Programme for the Conference on Professional development for IBSE in Pre-Secondary Education

Santiago, Chile, October 20-22, 2008

Venue: University of Chile, Salon Domeyko

Day 1 – Monday, 20th of October 2008

9:00 – 9:45 am	Inaugural Session - Dr. Jorge Allende, President of the Organization Committee - Dr. Victor Perez, President of the University of Chile - Dr. Servet Martínez, President of the Chilean Academy of Sciences - Dr. José Lozano, Regional Coordinator of the IAP/IANAS Science Education Program - Sr. Pedro Montt – Director of Curriculum ad Evaluation – Chilean Ministry of Education - Prof. Patricia Lopez-Stewart – Directora ECBI Program of the Chilean Ministry of Education
9:00 – 10:30 am	Overview and presentation of issues from background paper Dr. Wynne Harlen
10:30 – 11:00 am	Coffee/tea break
11:00am – 1:00 pm	4 Parallel group discussions Theme 1: Content and aims
1:00 – 2:30 pm	Lunch
2:30 – 4:30 pm	4 Parallel group discussions Theme 2: Tools
4:30 – 5:00 pm	Coffee/tea break
5:00 – 5:45 pm	Plenary Session: Report from discussion groups
6:00 – 7:00 pm	Meeting of GAC and Reporters
7:00 – 8:30 pm	Welcome Cocktail

Day 2 – Tuesday, 21st of October, 2008

9:00 – 9:45 am	Plenary Session
	Chair: Dr. Sally Goetz Shuler
	Plenary Presentation
	Dr. Wei Yu (China)
9:45 – 10:30 am	Plenary Presentation
	Dr. Pierre Léna: France and the European Union
10:30 – 11:30 am	Coffee/tea break
	Posters review
11:30am – 1:00 pm	4 Parallel group discussions
	Theme 3: Scaling up
1:00 – 2:30 pm	Lunch
2:30 – 4:30 pm	4 Parallel group discussions
	Theme 4: Evaluation
4:30 – 5:00 pm	Coffee/tea break
5:00 – 5:45 pm	Plenary Session: Report from discussion groups
6:00 – 7:00 pm	Meeting of GAC and Reporters

Day 3 – Wednesday 22nd of October 2008

9:00 – 9:45 am	Plenary Session
	Chair: Dr. Nicolas Poussielgue
	Plenary Presentation
	Dr. Rosa Devés: Chile and Latin America
9:45 – 10:30 am	Plenary Presentation
	Dr. Dyasi (USA)
10:30 - 11:00 am	Coffee/tea break
11:00 am	Summary and Recommendations
	Closure
	Dr. Jorge E. Allende

Appendix C

Plenary presentation summaries

Professional Development in LBD Project Wei,Yu
Key Laboratory for Child Development and Learning Science (SEU), MOE, China
Thinktank: Handsbrain Education, Jiangsu, China

Learning By Doing (LBD) Science Education Project is a pilot project of Inquiry Based Science Education and Learning in kindergartens and primary schools (age 5-12) in China. It was co-initiated by the Ministry of Education and the Association for Science and Technology of China in August 2001. After 7 years' operation, reaching out to 22 provinces and benefiting over 200,000 students and thousands of teachers, LBD has been recognized by public and government agencies as a sound foundation for revising the National Standard of Science Education and it continues to expand in China.

Professional development (PD) is identified as one of the nine key principles of LBD and is integral to the whole process of LBD project. We have developed 4 different models for PD activities for different participants and different stages, as listed in the table below

From the start of implementation, the project has laid stress on education as a branch of science. Education reform should be scientifically research-based. But of course education is more than that, for we strive to bridge the gap left in history on our way to enabling education research to advance the frontiers of learning sciences. The important task is capacity building in scientific research of IBSE, adopting what is relevant from advanced international experience at the same time as investigating Chinese practices.

Two research examples given in this representation - conceptual change of students and the cultivation of social emotion competency in IBSE - show that the applied research of learning science can really bring beneficial to the education policy making and practices. Social and Emotional Learning has been introduced into the content standard of LBD.

PD in LBD is being scaled up by three ways:
1 Using teacher training network already existed
2 Building cooperation between local scientists and teachers
3 On-line teachers' training, supported by the Internet and open resources

Among the uses of new information technology in LBD:

1. Handsbrain Network. In order to develop online study and communication for teachers, the Website of Handsbrain,-China Kindergarten and Primary Science Education Network was formally established in 2002.

2. BBS As a good platform for PD. In the internet, the BBS is also a good platform for communication. We set up a BBS to open resources and discuss reciprocally.

3. A Multimedia Database for PD. In order to enhance the PD and learning, it is necessary to develop research tools and establish research schools. Therefore we develop a multimedia database, which can contribute to IBSE at least in three important aspects. (1) Record individual pathways of learning and development; (2) Share teaching experiences by podcasts and videos; (3) Connect schools geographically to interchange information effectively.

Four different models for PD activities in LBD project

Model	Participants	Major Contents	Method	Duration
Introduction	Teachers and trainers get entrance to LBD	Introduction of Science, IBSE and LBD Instruction of IBSE Assessment of IBSE	Special Lectures Topic discussions Practices of IBSE Classroom visit Simulation of classroom activities	Two weeks
Modules Instruction	Teachers	Science concepts Experiment design Teaching strategies Implementation of formative assessment	Demonstration and simulation of classroom teaching Topic discussion Interaction between module developers and teachers	Three days for 1-2 modules
High Level Training	Teachers and trainers who have teaching experiences in LBD	Content Standard of LBD Core Concepts of Standard Curriculum design and case study Design of formative assessment	Lectures Topic Discussion Case study on classroom strategies Classroom visit Classroom teaching demostration and analyssis	1-2 days
National training for trainers	Trainers and researchers	Overview of the development of IBSE in the world Scientific basis of Learning science and child development Content Standard of LBD Strategies discussion and case study	Lectures Demonstration and discussion on strategies of PD Practices and analysis of PD	7 - 10 days

Professional development of teachers - News from France and Europe

Pierre Léna & Raynald Belay
La main à la pâte, France

The *La main à la pâte (Lamap)* project is now sufficiently known (e.g. **www.lamap.fr**) to need only brief description. Begun in France under the leadership of the Académie des sciences in 1996, it has progressively raised the proportion of classes having science lessons from a bare 3% to 30-40 % in 2008. As the French education system is highly centralized, the project had to be entirely discussed and approved by the ministry of education. This ministry produced in 2000-2003 a development plan of science education, inspired by the Académie and based on IBSE principles. Since then successive curriculum changes have been implemented in 2002, 2005, 2008, and while only the first one fully supported these principles they nevertheless remain in the later ones. Despite these intentions, however, there was no organized plan for teachers' professional development (PD), which was largely left to the initiatives the Académie could take. These were more formally recognized in 2005 by a multi-annual contract between the ministry and the Académie.

For over more than a decade, *La main à la pâte* has taken various initiatives to help PD. Many of them were offered to all interested teachers in the country, for example: distance support for teachers through a very active website (www.lamap.fr); specific training for thematic projects (e.g. *science & health*); yearly summer schools *Graines de science*, bringing teachers and scientists together (10 years); local coaching of teachers by scientists, in the national scheme ASTEP; a DVD for self-training, distributed in all schools in France (60,000 copies by November. 2008); a DVD for training in the specific connections between science and language acquisitions produced in January 2009; and dedicated training tools on *Lamap* website. In addition, *Lamap* established progressively 15 pilot centres for IBSE, involving a total of about 3000 classes, mainly in areas of difficult schools. A grid for observation and formative evaluation of IBSE classes has been constructed and has been applied systematically since 2007.

ASTEP is an important and growing system for teachers 'coaching by scientists' in which scientists may provide support in class or from a distance, promote collaborative projects between classes and the production of resources, etc. To address the *I do not know* syndrome of teachers dealing with science, distance support through Internet is based on a network of consulting scientists and experts in pedagogy. Answers are archived in a data base in which there are over 2000 items.

Since 2007, the observation grid (produced by E. Saltiel and M. Delclaux) has proved to be an efficient formative evaluation tool. In order to measure the progress in language, in investigation behaviour, in the progression of knowledge and in final knowledge acquisitions, several factors are observed: teacher activity, students' activity, written products, lesson content, use of materials. For each of the latter, there are several scenarios describing increasing 'IBSE relevance' and the observer notes the one most nearly matching the observed practice. All the teachers of a group can then be positioned with respect to IBSE practice, and understand how to improve it.

More focused sessions of PD are also organized. They follow some general principles: a consistency between what the teacher is asked to do and what he/she will ask the pupil to do; explicit comparison between traditional and IBSE practice; explicit discussion of the relation between content and pedagogy. Hence, a typical training scheme will be to go through a defined inquiry process (such as *How to measure the wind speed?*), the description and analysis of learning units, the production of pedagogical sequences, the search for additional resources to continue the lesson.

Beyond France, *Lamap* has taken several initiatives in Europe. These include projects - *Scienceduc* (involving 5 countries developed 2003-2005) making an inventory of actions, *Pollen* (12 countries, 2006-2008) which created 123 seed cities for IBSE - and the submission of a proposal, *Fibonnaci* (21 countries, submitted 2008), for a large scale dissemination of IBSE. All these projects have been funded by the EC. Teachers PD has a central role in them, including the production of resources for training, an inquiry pedagogy guide (by E. Saltiel, France), a training guide (by T. Jarvis, UK), and numerous exchanges of trainers across Europe.

The question of science education in primary schools has progressively become a important issue for the EU, as illustrated by several actions: the Rocard report *Science education now : for a renewed pedagogy* to the EU Commission (2007); the report *Science education in Europe* to the Nuffield Foundation (2008); the OECD Report *Stimulating the interest of students for science and technology* (2008); the EU calls (FP7) in 2008-2009, amounting to over 15 M€ for primary school science; the EU Conference *Science education in the Europe of knowledge* in Grenoble (Oct. 2008);and the Education Ministers' Council in Nov. 2008, albeit with a limited interest on science education. In addition, the InterAcademy Panel is creating an IAP European Focal Point (network) with science Academies to support EU and national policies.

After 12 years of *Lamap* developments, some lessons on PD can be drawn, despite the fact that PD for science has never really been a priority for the ministry of education in France. Teachers' PD is strategic for IBSE development but the scale on which it is needed (300.000 teachers in France) makes the task difficult in terms of cost and design, raising a number of questions: should there be a centralized organization or a disseminated process? How to extend to new ways of training, which may carry some risk? What role can scientists and engineers take? Distance training with increasing use of Internet is certainly very powerful, but are there new ideas to make it more attractive and efficient? New knowledge on the learning process also needs to be taken into account. Can teachers progressively acquire better understanding of 'How the brain works' and include the role of emotion (cf. the work carried out in China by the project *Learning by doing*). Finally, there are research questions to be addressed, such as: *How do teacher understand science, how much do they have to understand it?* (for example, what is their understanding of evidence?).

Professional learning strategies

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The Inquiry based Science Education Program (ECBI) has been in operation in Chile for the past five years. It is a joint initiative of the Chilean Academy of Sciences, the Ministry of Education and six universities in different regions of the country. At present it reaches approximately 200 public schools. The majority of the approaches and challenges of the ECBI-Chile Program are common to those of similar science education programs which are currently being implemented in other countries of Latin America, including Colombia, Brasil, México, Panamá and Venezuela.

The ECBI program is inspired by the belief that all children have the right to receive good quality science education and that achieving this goal, requires the intense involvement of teachers and those around them, including teacher educators, scientists and policy makers. The ECBI Program is understood both as a vehicle to improve science education and also an agent of change for the schools.

The ECBI program is a network of people and institutions that learn together from their interaction and through practice. The organization is based on a triad of cooperation that includes the ministry, universities and the districts with their schools and capacity building is addressed as a collective phenomenon. Transfer strategies have been devised to ensure that the program replicates its most valuable characteristics, but also allow and stimulate its evolution. Professional development activities are designed so that all members of the program strengthen their competences. The organization as a network of institutions with different nodes linked to the universities (the ECBI Centers) is a fertile ground for the development of leadership. The biggest challenge at present is to create the conditions to develop leadership at the level of the school.

Five main strategies for professional development can be distinguished:

1. Initial workshops for teachers and principals.

In these workshops principals and teachers develop a shared vision and teachers learn about inquiry and science content by becoming involved in similar learning situations as those that will be experienced by the children. At the same time they plan for the management of the program at the level of the school.

2. “In the classroom” or “in the school” professional development.

Teachers receive direct support from a monitor that has been specially trained by the program to facilitate the adoption of the methodology. In the early stages of the program the monitors devoted two hours per week to lesson planning and evaluation with individual teachers and spent a similar time in their classroom. With the expansion of the program the direct teacher – monitor interaction has become less frequent, and the one to one relationship is being replaced by group planning and evaluation and by a guided process of production of new inquiry lessons which takes into consideration the different levels of expertise of the teachers.

3. Curriculum development.

An important professional development strategy, which has so far involved only a selected group of teachers who have demonstrated higher competency, is the development of new teaching material. The objective of these activities is not only to produce good quality teaching resources, but also to build capacities in the process. The development of the units is the responsibility of a team brought together by an educator, a teacher and a scientist and has been especially important for the construction of nearness between all participants and to connect the scientist to the reality of the school.

4. Transfer.

One of the objectives of the program is to progressively extend its reach. This requires a thoughtful plan to prepare the teams, to access decision-makers, detect and attract potential leaders and provide assistance and training at the start of the new programs. The program collaborates in the development of these capacities through strategic planning workshops following the model developed by the National Sciences Resources Centre (USA). This approach has been essential for the expansion of the program in Chile and also for the transfer to other countries in Latin America (Panama, Venezuela, Bolivia and Peru).

5. Internships.

The program also offers internships recognizing the ECBI schools as effective training centers. These internships have two main purposes: to train leaders that will initiate projects in a different context (private schools, foundations) and to collaborate in the approximation of different professionals to education.

In a recent evaluation process that was requested by the Ministry of Education to the Pontificia Universidad Católica de Valparaíso and which was supervised by a committee of the Inter Academy Panel the following main aspects were evaluated:

a) the opportunities offered by the ECBI program for the professional development of teachers and monitors,
b) the quality of materials offered for their use and
c) the support offered by administrators of the schools committed to the implementation of ECBI.

Among other observations regarding professional development it was pointed out that the initial workshops and the presence of a monitor that supports the teacher in the planning and the development of the lessons are found to be effective strategies to initiate teachers into ECBI. However, it was remarked that advancement towards a deeper understanding of the inquiry process could require other types of interactions between teachers and monitors than those which are at present being used. The actual focus of the professional development activities seems to be learning to teach with the inquiry units, and as a result inquiry, experimentation and the learning cycle are often understood to be synonymous, suggesting a need for a broader view of inquiry-based teaching.

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Introduction

The teacher professional development programme summarized in this account has been carried out over thirty years at the City College of the City University of New York in Harlem, New York and has served teachers from the northern parts of Manhattan and much of the South Bronx where African-American and Latino students comprise over 93% of the school population. A major part of the programme takes place at a teachers' center at the university. The center is home to a wide range of delightful phenomena and to rich physical, intellectual, and print and computer-based resources that invite teachers to engage in self-directed firsthand and secondary scientific inquiries. It is suitable for group and individual work and for professional gatherings.

The programme consists of two parts: a Summer Institute, and an academic year during which teachers meet weekly in school-based groups to engage in science inquiries in science areas they teach in their classrooms; they implement what they learn in the programme, with long-term on-site support by program staff. In the weekly meetings they discuss and reflect on their classroom implementations and on ways to improve their practice and assessment of students' ongoing learning. Both parts enhance teachers' learning and understanding of authentic inquiry-based science education; they increase teachers' capacity to cultivate students' abilities to successfully engage in science inquiries for the acquisition of important science knowledge and practice. This summary focuses only on the Institute.

Elements of a Summer Institute

The intensive Institute is carried out daily over a four-week period of the summer vacations. Teachers engage in firsthand transformative science inquiries of their own choosing, at their own level. They choose phenomena of nature commonly found in their students' and their own communities and suitable for teaching primary school science (e.g. electricity, sound, light, living things, seasons, physical structures, etc.). Mostly, they work individually but also in formally established advisory (small) groups that meet at strategic points during the Institute. The advisory groups serve as support and examine and enrich the progress of their member's inquiries and help relate them to assigned science and professional literature. Throughout, teachers are supported by staff (advisors). At the conclusion of the Institute, each teacher presents and defends her/his science inquiries at a "science research council conference" with the rest of the teachers and staff constituting a critical but friendly audience. She/he also submits a comprehensive reflective account of experience in the Institute.

Example of a teacher's intensive science inquiries

In one summer institute, Julie chose to carry out a science inquiry on feathers. During her inquiries, she made important learning decisions at several critical points. For example, after a preliminary examination of down feathers, she made a decision:

> The down feathers I found seemed very different than the pillow feather. *I would need a magnifying glass to see it more clearly, and then perhaps I'd use a microscope as well*…The first thing I did on Monday morning at the Center was to find a magnifier and a microscope. I had found a powerful microscope and magnifying glass; so I started to examine the down feather closely, first with the magnifier…I wanted to get a better look so *I decided* to use the microscope. *I used a 100x magnification…* (emphasis added)

She further wrote:

> *I decided* to draw what I had seen so far. I returned the microscope to a lower magnification and began to draw the basic structure and the buds on one feather branch.

As she studied a down feather under the microscope, Julie made interesting observations, which she shared with others:

> I turned to the lens that increased magnification 400x and worked the focus dial and the light bulb many times and was then able to see that there were little hairs or hooks on the hairs that were hooking onto other hairs. I was so excited about this "find" that I called the people near me to come and take a look at this.

When she increased the magnification to 600x she reported:

> The branches had what looked like beautiful wood grains throughout. They no longer appeared smooth and soft but rough and hard. I moved the feather until I could find a hook to focus on. When one came into focus it looked like a huge thorn on a rose stem. The hook itself had numerous jagged teeth. *I invited other students over to see what I had found. Other teacher/students began calling me to see their discoveries. At lunch time discussions were less and less about such things as dropping the course, or the struggle to find something to study, but more and more about how an ant colony was protecting its eggs from invader ants; the variety of colors that were in the weeds found around the college when boiled in water; how much fun it was to "play" with marbles…*These particular small group activities had forced us, in a certain sense, to actively make some discoveries and interact closely with each other. We had a wonderful opportunity to talk, share ideas, laugh together, and learn by doing…(emphasis added)

She also described how she compared a down feather to a peacock's and found that the latter seemed larger than those of the down and that the hairs on a single branch did not go continuously up the branch, but were symmetrically placed in clusters. At higher magnification, she found that unlike in the down feather the hook itself in the peacock's feather had numerous jagged teeth. She compared both feathers to a gull's feather and found similarities and minor differences. She asked several questions and found out that

> a single drop of water on the feather seemed to make the weave tighten even further...with a drop of oil, the sense of weave seemed to disappear altogether, there was a pattern but it was totally different. Now it looked like smooth hills and valleys. I pulled some hairs apart and saw thick limp ends. The ends were drooping and it looked as if thick icicles were pulling them down. The patterns were visible again but the texture seemed much less firm. I decided to try this again and to photograph it as quickly as possible… With Stan's help, we slightly pulled the branches apart. The hooks seemed to slide a little and this made the feather flexible. Perhaps in flight the bird controls the air passing through it. Or could the tightening help keep in body heat?

In her comprehensive reflective report, she described the role of the staff; for example, earlier in the Institute, as she was examining a down feather under the microscope,

> Stan (an advisor) came over and I showed him what I had found and *asked if it would be possible to photograph it through the microscope*. I knew nothing about photography and Stan said he would be happy to give me a lesson on how to develop the film and make negatives the following day.

She also reported that

> Kent (an advisor) spent a good deal of time with me as I learned how a camera worked. Two other people came over and joined this lesson. When we mounted the adapter and the camera and began to examine the down feather, two problems became evident…I spent a great deal of time trying to get the mirror to increase the amount of light into the microscope. It did not seem to help…I talked to Alice, an advisor, about my problems. She suggested removing the mirror and have the light go directly through the microscope instead of reflecting it from the mirror…The next morning I took Alice's advice and tried to remove the mirror. This became a task in itself. Finally, with the help of Alice and Henny (another staff) *we did it*. I had been to the point of tears over the last two days because of my own inability to handle the tools at hand. (emphasis added)

The Institute often opens up teacher's curiosity about, and interrelatedness of many apparently disparate phenomena. For example, Julie wrote that near the end of the Institute

> I stopped next to a container on the floor which held a patchwork quilt. The different pieces of the fabric had different weaves to them. The tight weave of one piece of fabric seemed very familiar to the weave of the down feather with water on it. Feathers apparently have some natural oils and I began to wonder about the tightness of the weave in waterproof raincoats, and what type of oils might be used to bring about waterproofing. Does the weave tighten as it did with my feathers when I put water on it? Here was a thread! Seeing how things in the world around us are interrelated. I felt excitement all over again.

Concluding Remarks

Through the science inquiries she had designed, carried out, and interpreted, Julie generated and acquired significant science facts and concepts associated with feathers – detailed structures, different types with different functions (flight, contour, tail, and down feathers), and properties (lift, steering, braking, insulation or heat retention, waterproofing). She also became familiar with standards of scientific evidence associated with generating the facts and concepts.

She answered her own questions, for example:

> When there are oil spills, and birds and ducks have their feathers caught in this, what happens to the structure of feathers? What happens to the structure of the pattern when it rains? How do the hooks reconnect when the feathers have been ruffled? When oil is washed off the feathers by man, how do soap and water affect the ability of the hooks to reconnect? Do all birds' feathers have basically the same structure and function? If they differ, what is the purpose of those differences?

She learned the use of the physical tools of inquiry-based science, e.g. magnifiers and microscopes at different magnifications, taking photographs through the microscope and making micrographs. She overcame difficulties when using the equipment – removing reflective mirror from the microscope to avoid incident rays, getting enough light to shine through the specimen under the microscope, setting the right magnifications, and so on.

Julie's reflective account demonstrated that advisors' responsibilities in the Institute are very complex and delicately balanced between success and failure. As the account shows, a teacher's progress in the Institute has peaks and valleys, excitement and discouragement, and frustration and exhilaration and every staff member must make informed decisions about when, how, and to what extent he/she should enter into or leave a teacher's science inquiries without interfering with its trajectory. Above all, there must be mutual trust between learner and advisor. She made repeated references to collaborative learning among teacher participants, which enriched all involved.

Julie carried her experience to her kindergarten classroom and engaged her students in appropriate productive science inquiries, which they fully recorded through drawings throughout the school year.

Appendix D

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