INQUIRE Course Manual

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The following institutions are partners in the INQUIRE project:

- University of Innsbruck, Austria
- Royal Botanic Gardens, Kew, UK
- King's College London, UK
- Museo delle Scienze, Trento, Italy
- University of Sofia, Bulgaria
- Agencia Estatal Consejo Superior de Investigaciones Cientificas, Spain
- University of Bremen, Germany
- Jardin Botanique de la Ville de Bordeaux, France
- National Botanic Garden of Belgium
- Schulbiologisches Zentrum, Hannover, Germany
- Natural History Museum Botanical Garden, Norway
- Coimbra Botanic Garden, Portugal
- Moscow State University Botanical Garden, Russia
- University of Lisbon, Portugal
- Botanischer Garten, Rhododendron - Park, Botanika, Bremen, Germany
- Botanic Gardens Conservation International, UK
- Universidad de Alcala, Spain

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About the INQUIRE Project

INQUIRE was a three year project (2010 -2013), within the “Science in Society’ Programme of the European Commission, focusing on Inquiry-Based Science Education (IBSE) and involving 17 partners in 11 European countries. The project was generously funded by the European Union under the 7th Framework Programme. Fourteen botanic gardens were involved in the project and individually developed and evaluated their own IBSE teacher training course. INQUIRE was coordinated by Innsbruck University Botanic Garden, Austria, with support from Botanic Gardens Conservation International (BGCI) and two highly respected universities – King’s College London, UK and the University of Bremen, Germany. The content of the courses focuses on biodiversity loss and climate change which are recognised, in the scientific world, to be the major global issues of the 21st Century.

Our aim is for INQUIRE to act as catalyst, training and supporting increasing numbers of teachers and educators to develop their proficiency in IBSE and become reflective practitioners. Following on from the pilot course development and evaluation, it is hoped that these current INQUIRE courses will prove inspirational, drawing in many teachers and educators to develop and promote inquiry-based learning Eventually, it is hoped that course participants will go on to inspire the many schoolchildren that pass though their hands.

For more information about INQUIRE visit: **www.inquirebotany.org**

Introduction

This manual is designed to support teachers and educators taking part in inquiry-based training courses running in botanic gardens or similar environmental education sites. Providing useful notes on IBSE and reflective practice, it should be read in conjunction with the booklet that provides exemplar IBSE activities and lesson plans.

Part 1 provides brief background information on IBSE methodology, highlighting its strengths and benefits as well as the barriers and solutions to its implementation. Additional information on other relevant IBSE projects in the national and European context can be found in **Appendix 1**

Part 2 of this manual focuses on assessment and evaluation, introducing the concept of a community of practice and promoting continuous reflective practice during teaching. It provides a guide to self-evaluation, illustrating ready-to-go techniques for evaluation and data collection as well as introducing a framework for formative and summative assessment and action research.

Part 3 outlines the planned course modules, including topics, the focus of scientific inquiry, and timing. This section also includes details on practical aspects of course implementation, including preparation for each session. Further information can be found in **Appendix 2**.

The manual is available in 10 languages (English, German, French, Spanish, Portuguese, Italian, Norwegian, Dutch, Bulgarian, Russian) and can be downloaded from **www.inquirebotany.org** in the resources section for each language.

IBSE activities at Cambridge University Botanic Garden

Role of Botanic Gardens and LoTC sites

Botanic Gardens are some of Europe's most inspirational cultural, scientific and learning institutions. They contain amazingly diverse collections of plants and plant artefacts and hold extensive botanical, ethno-botanical and horticultural knowledge and skills. Most European botanic gardens are situated in urban areas and this makes them accessible to large numbers of people. With more people living in cities, botanic gardens offer some of the only outdoor learning sites for children to gain first-hand experiences in IBSE.

Through INQUIRE courses, teachers and educators will be supported to develop inquiry-based activities and resources that can be used in the classroom or on a visit to a 'Learning Outside the Classroom' (LOtC) site such as a botanic garden, arboretum, natural history museum, nature reserve, environmental education centre or natural habitat. Participants are encouraged to build their subject knowledge in climate change, plant diversity and plant and habitat conservation and to enhance their teaching skills in IBSE. There are opportunities to see, plan and implement a range of innovative activities with the support of relevant LOtC staff.

Part 1: IBSE explained

Background to IBSE

The INQUIRE project is based on a broad understanding of IBSE, which takes into consideration the wide range of definitions of and approaches to IBSE that exist. The project includes 11 European countries with different educational systems. Within those countries, a variety of IBSE approaches has emerged and are still emerging. In addition, science itself is a broad church. Cosmologists work in very different ways to industrial chemists; epidemiologists practice a very different kind of science to volcanologists. So, if students are to appreciate the full range of scientific practices, then trying to promote a single 'scientific method' is going to narrow students' understanding of how science works rather than expand it. A more fulfilling science education would encourage students to appreciate not just the wonder of science but also the role of scientific inquiry and scientists in society (Dillon *et al*., 2011)

What is inquiry based learning?

To facilitate inquiry-based learning, one needs to perceive the progression from teaching science as an activity concerned mainly with accumulating unchangeable knowledge to appreciating science learning as a student-centred process of constructing and acquiring knowledge. The latter position mimics scientific inquiry, which is characterised as a multifaceted activity that involves making observations; posing questions; examining books and other sources of information to see what is already understood; planning investigations; reviewing what is already known in the light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations and predictions, and communicating the results.

Scientific inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations by finding answers to questions (NRC,1995, p.23).

Minner, Levy and Century (2010) argue that the term 'inquiry' refers to at least three distinct categories of activities:

- 'what scientists do' (e.g. conducting investigations using scientific methods),
- 'how students learn' (e.g. actively inquiring through thinking and doing into a phenomenon or problem, often mirroring the processes used by scientists),
- and a pedagogical approach that teachers employ (e.g. designing or using curricula that allow for extended investigations)' (p. 476).

They go on to argue that the act of inquiry, whoever is involved, has, at its heart, a number of core concepts which the US National Research Council identifies, from a learner's perspective, as ''essential features of classroom inquiry'' (NRC, 2000, p.25) including:

(1) Learners are engaged by scientifically-oriented questions.

(2) Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically-oriented questions.

(3) Learners formulate explanations from evidence to address scientifically-oriented questions.

(4) Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.

(5) Learners communicate and justify their proposed explanations.

In April 2011, Wynne Harlen summarised what had been written about IBSE and presented **two** definitions:

Inquiry-based science education means students progressively developing key scientific ideas through learning how to investigate and building their knowledge and understanding of the world around. They use skills employed by scientists such as raising questions, collecting data, reasoning and reviewing evidence in the light of what is already known, drawing conclusions and discussing results. This learning process is all supported by an inquiry-based pedagogy, where pedagogy is taken to mean not only the act of teaching but also its under-pinning justifications (IAP Report of a conference held in York, UK, October 2010).

Therefore **inquiry-based teaching** leads students to build their understanding of fundamental scientific ideas through direct experience with materials, by consulting books, other resources, and experts, and through argument and debate among themselves. All this takes place under the leadership of the classroom teacher (NSF, 1997, p.7) – or, in the case of the INQUIRE project, the botanic garden educator.

Inquiry based learning in INQUIRE

IBSE in INQUIRE takes place in a unique learning environment created within a school and botanic garden partnership. It builds on a range of knowledge and resources provided by this collaboration. INQUIRE learning is not about memorising facts – it is about working with living organisms (mainly plants), observing natural phenomena, formulating questions, linking evidence to explanations and finding appropriate solutions to explain observations and address questions and problems. Through what may be simple tasks or complex undertakings, learners are always led to experience the excitement of solving a question or problem themselves, usually as part of a team.

The INQUIRE learning environment promotes an active, student-centred and student-led learning approach based on constructivist theories of learning. INQUIRE learning ties in students' already existing ideas right from the start and tries to support conceptual reconstruction processes (Duit & Treagust, 2003). It integrates science learning across each of the three following domains:

(1) The conceptual structures and cognitive processes used when reasoning scientifically.
(2) The epistemic framework used when developing and evaluating scientific knowledge.
(3) The social processes and contexts that shape how scientific knowledge is communicated, represented, argued and debated. (Duschl & Grandy, 2008)

The pedagogy includes teacher-designed assessment that monitors learning and provides feedback on thinking and learning in each of these three domains (Duschl & Grandy, 2008; Dillon & Osborne, 2011).

Student IBSE activities at MSU, Russia

Inquiry-based teaching in INQUIRE

When it comes to putting this approach into practice, teachers and educators need to be aware that students might not see what they are meant to see and may not draw the conclusions they are expected to draw. Things that are 'obvious' to someone who knows the answer are not obvious to someone who doesn't. In addition, inquiry-based teaching assumes that theoretical ideas and constructs 'emerge' from observation of phenomena. Although the constructivist approach grew out of a critique of discovery learning, it did not solve the problem of how to get scientific ideas 'into play' (Dillon et al., 2011).

Justin Dillon (2011) has summarised teaching and learning aspects that have been shown to make a difference:

Questions play a crucial role: The issue of ownership of a question is important – which is why successful teachers can involve students in generating their own ideas for investigation.

Knowledge development is a continuing process: Students need to be able to see that science is about showing why ideas are wrong as much as it is about showing that other ideas work. Learning about the history of ideas and their development; the accumulation of evidence and observations can be helpful in teaching the nature of science (Osborne & Dillon, 2010).

Practical work needs to be selected carefully: Learning in IBSE is more effective when teachers reflect carefully on the effectiveness of the practical work they use, identify clear learning objectives for each practical task, think about the talk and other activities that surround a practical task and endeavour to ensure students can understand the purpose (in terms of answering a question that has become their own or advancing their knowledge) of every practical task (Abrahams & Millar, 2008).

Discussion processes are essential: The role of discussion is important because it is through talk that ideas move from the world into our heads (Bell, 2004). We literally 'make sense' of what we see through re-presenting (for example, by talking) to other people what happened and why.

Skills need to be practised in context: Scientific skills are preferably practised in context. Too often students practise skills out of context and then fail to appreciate how they can be applied. This comment is as true of such skills as drawing a graph as it is of more physical skills such as measurement. Observation, which is really two skills, taking readings and identifying patterns, can be developed through practice, coaching and feedback.

Assessment plays a powerful role: As with much of education, the role of assessment is key. Atomistic summative (end-of-topic) tests are generally less help to learners than formative assessment. Students need to know how good they are at scientific skills, what they're not doing well and how to

IBSE activity in the classroom, part of the INQUIRE course at NBGB, Belgium

improve. International comparisons, nation or state-wide tests restrict teachers' focus on the broad range of scientific skills and processes that they encourage their students to develop.

Learning out of school doors adds value: Out-of-school activities provide an opportunity for students to develop a richer understanding of how scientists work (NRC, 2009). The NRS reported that there is "mounting evidence that structured, nonschool science programs can feed or stimulate the science-specific interests of adults and children, may positively influence academic achievement for students, and may expand participants' sense of future science career options" (NRC, 2009, p.2).

Learning with and from scientists: Finally, few students engage with scientists on a regular or frequent basis. Not surprisingly, their stereotypes of scientists tend to match those found more widely in society. In teaching how science works, we also need to address the questions, who are scientists and why do they do what they do? We need to create the conditions in which all students have the opportunity to see and consider themselves as potential scientists even if, in the end, they opt for different careers.

Conclusion: In conclusion, there are no panaceas in science education and while well-planned and delivered inquiry-based science has much to offer, it is only part of effective science teaching and learning. What matters in science teaching in general, and in inquiry-based teaching in particular, is that science educators think carefully about their aims and about whether the approach that they are using to teach science promotes sufficient challenge and provides enough opportunities for students to collaborate on meaningful activities that can lead to greater knowledge and understanding of science. They also need to consider how science and scientists contribute to society within a broad social, cultural and historical context (Dillon et al., 2011).

Common misunderstandings about IBSE

Although many policy makers and educators promote inquiry-based science education as a new approach to science education, the idea has been around for some time. Over the years, a number of misconceptions have emerged and this section lists the common ones and explains why they are not correct.

IBSE must include hands-on activities: Many scientists don't use experiments in their day-to-day work. It is possible to build scientific knowledge by looking for patterns in data such as the distribution of plant species or the flowering times of plants. IBSE can involve the analysis and manipulation of data using computers and it does not need to involve hand-on activities. What does count is that any activity must be 'minds-on'.

Taking part in IBSE is like 'being a scientist': It is probably more accurate to say that taking part in IBSE can help students to develop their science skills. Being a scientist often involves reading the scientific literature, seeking funding, developing a team and working over an extended period of time.

Teachers can't tell students anything during IBSE: Some years ago a number of science educators appeared to advocate an extreme view of IBSE in which teachers could only ask questions to encourage students to carry out their inquiries. This approach did not work and frustrated teachers and students alike. The secret of successful IBSE is balancing the students' need for information and their need to be left alone to work things out in their groups. Giving students information is fine; giving them too much information is not.

IBSE is better than other teaching strategies: The evidence for the effectiveness of IBSE is somewhat contradictory. In some cases students learn more effectively when teachers use IBSE. In other cases, other teaching approaches can be just as effective. A good demonstration can be a powerful way of teaching students a new technique.

Students prefer IBSE over other methods: Not all students like IBSE methods: some prefer other strategies. The evidence from research is that students tend to enjoy a mix of activities and can be bored if teachers use only one approach. Sometimes students need to be motivated to engage with IBSE methods.

It's difficult to assess IBSE: A range of assessment strategies for IBSE have been tried and tested. They include strategies for assessing the quality of discussions that students have with each other; the quality of students' planning and carrying out of inquiries, and, the level of presentation skills that students show when talking about their results. There is no 'right way' to assess IBSE.

Teachers can be trained to use IBSE quickly: Some teachers find IBSE difficult to implement. Teachers who have a narrow view of the nature of science may find it difficult to use IBSE methods. Age is not an issue – what counts more is the teachers' commitment to exploring new ways to teach science and their ability to try out new approaches.

Benefits of IBSE and perceived barriers to implementing IBSE

The NRC (1996 p. 105) reports that inquiry teaching develops scientific knowledge and understanding through processes such as predicting, collecting data, experimenting, analysing data and drawing conclusions. This can be through full inquiries, where students make more choices, such as:

- creating their own scientifically oriented questions;
- giving priority to evidence in responding to questions;
- formulating explanations from evidence;
- connecting explanations to scientific knowledge;
- communicating and justifying explanations to partial inquiry, which relies on more teacher direction in one or more ways (NRC, 2000, p. 29).

Inquiry science, particularly stemming from authentic questions, enables students to learn scientific concepts and processes, understand how a scientist works (NRC, 1996) and allows them to construct their own understanding of real-world problems. This is distinct from verification laboratory work, where students seek the single 'right' answer. IBSE activities, constructed to include experience of designing investigations, engage students in important hands-on, minds-on experiences with experimental processes (Wenning, 2005) teaching students to think. Further benefits of IBSE include the focus on understanding over memorisation and that students learn to construct an accurate knowledge-base through exploration, dialogue and argument. IBSE is a more dynamic, cooperative and accumulative approach to learning that promotes not only learning of content but values and nature of science. Within a botanic garden setting, IBSE also offers a more accessible learning opportunity for the very broad spectrum of schoolchildren who visit.

Although there are many potential benefits to using IBSE in a science classroom, studies show that teachers (and educators) face challenges in implementing inquiry (Abd-El-Khalick et al., 2004; Crawford, 2000; Krajcik et al., 1998; Lee and Songer, 2003). Anderson (2002) considered that science teachers' beliefs and values about students, teaching, and the purpose of education influence their adoption and implementation of inquiry. He described three barriers or dilemmas: technical, political and cultural. Successful teaching of inquiry is challenging for most teachers, particularly those new to the method. Hayes (2002) found that pre-service teachers struggled in their new roles as teachers of inquiry particularly with letting go of the didactic approach, going with students' interests, and asking the right questions. Some teachers worry about not having control over their classrooms during inquiry

Students investigate seeds from fruit at NHM, Norway

activities (Deters 2004; Keys and Kennedy, 1999; Windschitl, 2004) or claim that their students are not capable of carrying out inquiry projects (Crawford, 1999; Hogan and Berkowitz, 2000; Keys and Bryan, 2001; Wallace and Kang, 2004; Windschitl, 2004).

Changing from a teacher/educator who explains everything to a facilitator who supports the students in finding their own solutions and provides help only when needed requires confidence. Crawford suggests that ‘‘one possible reason that inquiry-based instruction remains a vision in the reforms, but an enigma in the classroom may lie in the fact that teachers have few operational models’’ (Crawford 1997, p. 16). Most science teachers did not experience inquiry in their own education, so they are unsure of what inquiry looks like and what their role(s) might be in helping students develop scientific understandings through an inquiry process (Abd-El-Khalick et al., 2004; Crawford, 2000; Trumbull et al., 2005).

Contextual factors also influence whether IBSE is implemented by teachers such as assessments which may not include inquiry-based learning, overloaded curricula or unsupportive head teachers, students and parents (Deters, 2004; Hogan and Berkowitz, 2000; Keys and Kennedy, 1999; Wallace and Kang, 2004). During a visit to an outside site, such as a botanic garden, there are further challenges for educators. Teachers have high content delivery expectations of educators in LOtC. Designing a visit that is inquiry-based and rich in the content that LOtC sites are uniquely placed to provide, within a limited time frame, is challenging – particularly when working with unfamiliar groups. Educators therefore need to be extremely flexible with the programmes on offer.

Part 2: Reflective practice: evaluation and data collection techniques

Continuous reflective practice during teaching

Teachers' professional learning starts with their pre-service teacher training and should continue through their whole working life. Lifelong learning enables teachers to act as experts in the profession of teaching in a world where scientific knowledge is permanently changing. According to Shulman (1986) teachers' knowledge is characterized by subject knowledge (knowing about subject content), pedagogical content knowledge (knowing how to teach the content) and pedagogical knowledge (knowing how to teach more generally). Further factors that influence teachers' professional acting are teachers' beliefs related to the subject and its teaching (Bishop, Seah and Chin, 2003), motivation, interest and self-efficacy (Krauss et al., 2004) and teachers' self reflection about their own work (Tirosh and Graeber, 2003). Teachers' professional development depends on their culture of reflection (Altrichter, Posch, Somekh, 1993). Bearing this in mind our concept of professional development will be built on repeated cycles of planning, implementation and reflection. Practitioner research is increasingly advocated as a self-reflection tool that can promote the development of teachers and researchers (Morris & Barker, 2003, Dillon et al. 2002, Elster, 2009).

In INQUIRE courses, participants work together in Communities of Practice (CoP). The term stems from the theories of situated learning and describes the cooperation of teachers with researchers and other teachers or educators (Lave and Wenger, 1991; Wenger, 2004). The main goals of the CoP are to improve learning and teaching skills, to share responsibility for professional growth, and to partake in professionally guided discourse about one's own teaching and learning. During the INQUIRE course you will be encouraged to reflect on many things including personal and team aspects of the project. The reflective learning and writing process are ongoing and you should seek to improve over the course. It is important to be honest and objective in your reflective writing. This Section presents practical suggestions, ideas, methods and strategies for reflective research in educational settings.

What is reflective practice?

A simple definition of reflection can be 'consciously thinking about and analysing what you are doing and what you have done; thinking about what and how you have learnt. There is a lot of theory behind reflection that can be very complex. Most of the theory relates to seeing reflection as part of the cycle of learning. Initially learners focus on knowledge, comprehension and application of subject matter. These three levels of learning are the easiest especially if the application is in a limited context, e.g. problems from a text-book. For higher levels of learning (application of knowledge in real world problems) you must be able to analyse, synthesise and evaluate. Reflection is a key part of moving into these higher levels of learning. The concept of reflective teaching and reflective action originates in Dewey's (1933) work *How We Think*. Reflective action involves a willingness to engage in constant self-appraisal and development. An aim of the INQUIRE project is to instil techniques required for partners to constantly reflect on their practice while conducting IBSE.

Within the INQUIRE course, we encourage participants to develop their technical efficiency in relation to IBSE. We encourage you to monitor, evaluate and revise your own practices using data collection (assessment and evaluation) techniques. We also encourage course participants to collaborate, share and discuss with colleagues at work and within the course in order to support your learning and professional development. Opportunities for reflection should occur before, during and after activities (such as sessions on the INQUIRE course, or when you try a new approach on other courses). That way you can take note of your learning starting point, assess your progress through the project and critically evaluate your learning at the end of the activity. Critical reflection is the process of analysing, reconsidering and questioning experiences within a broad context of issues (e.g., issues related to IBSE, curriculum development, learning theories, politics, culture, or use of outdoor space).

Guidelines for reflections	
Description	What is the stimulus for reflection? (incident, event, theoretical idea) What are you going to reflect on? Describe what happened and set the scene.
Feelings	What were your reactions and feelings? What did you think and feel?
Evaluation	What was good and bad about the experience? Make value judgements.
Analysis	What sense can you make of the situation? Bring in ideas from outside the experience to help you (literature, what you've learned on the INQUIRE course). What was really going on?
Conclusions (General)	What can be concluded, in a general sense, from these experiences and the analyses you have undertaken?
Conclusions (Specific)	What can be concluded about your own specific, unique, personal situation or ways of working?
Personal Action Plans	What are you going to do differently in this type of situation next time? What steps are you going to take on the basis of what you have learnt?

Tools for reflective practice

A reflective approach to teaching involves changes in the way we usually perceive teaching and our role in the process of teaching. Teachers and educators who explore their own teaching through critical reflection develop changes in attitudes and awareness that can benefit their professional growth as teachers/educators, as well as improve the kind of support they provide their students. Teachers and educators engaged in reflective analysis of their own teaching report that it is a valuable tool for self-evaluation and professional growth. The following approaches to critical reflection reflect these processes – many can be used alone or with a supportive colleague.

Recording Lessons: Audio or video recording of lessons can also provide a basis for reflection. Many things happen simultaneously in a classroom, and some aspects of a lesson cannot be recalled – recording highlights the advantages and disadvantages of the various approaches undertaken during the lesson. It would impossible to attempt to recall the proportion of Yes-No Questions to WH-Questions a teacher used during a lesson; many significant classroom events may not have been observed by the teacher, let alone remembered. Recordings of actual lessons can supplement diaries or self-reports (see below). A recording may be achieved simply by locating a digital recorder in a place where it can capture the exchanges that take place during a lesson. Where digital video facilities are available in a school, a lesson can be recorded to capture as much of the interaction of the class as possible – both teacher to class and student to student. Once the initial novelty wears off, both students and teacher soon forget the camera, and the class proceeds with minimum disruption.

Written accounts of experiences: Another useful way of engaging in the reflective process is through the use of written personal accounts of experiences such as diaries/journals. Journal/diary writing is a valuable tool for developing critical reflection. The goal of journal/diary writing is:

- to provide a record of the significant learning experiences that have taken place;
- to help the participant come into touch and keep in touch with the self-development process that is taking place for them;
- to provide an opportunity to express, in a personal and dynamic way, their self-development;
- to foster a creative interaction with the process that is taking place.

While procedures for diary keeping vary (are you a paper and pen diarist, a tweeter, a contributor to an online forum, or a blogger?), the participant usually keeps a regular account of learning or teaching experiences, recording reflections on what he or she did as well as straightforward descriptions of events, which may be used as a basis for later reflection. The diary serves as a means for interaction between the writer, the facilitator, and, sometimes other participants.

Conversations and observations with colleagues: Peer observation can provide an opportunity for teachers to view each other's teaching in order to expose them to different teaching styles and to provide opportunities for critical reflection on their own teaching. Through conversations with colleagues (or participants on the INQUIRE course) you can probe further into aspects of teaching behaviours; discuss critical incidents and explain/justify aspects of teaching behaviour.

What is action research?

Action research is research that is carried out in practice, which informs practice – a quest for knowledge about how to improve. It typically is undertaken in a school or LOtC setting and is a reflective process that allows for inquiry and discussion as components of the “research.” It is often a collaborative activity among colleagues searching for solutions to everyday, real problems experienced in classrooms, or looking for ways to improve instruction and increase student achievement.

Action research allows practitioners to address those concerns that are closest to them, ones over which they can exhibit some influence and make change rather than dealing with the theoretical. It involves people working to improve their skills, techniques, and learning how we can do things better. It is about how we can change our instruction to impact students. The process of action research assists educators in assessing needs, documenting the steps of inquiry, analyzing data, and making informed decisions that can lead to desired outcomes. It is practical but it is also systematic and requires the practitioner to justify their claims with evidence and making the claims public.

Personal reflection - Using Published Research

Read and reflect on this group of pre-service teachers who reflect on their experiences of learning to implement inquiry techniques in their teaching – how might you research your practice?
Reference: Rita A. Moore, Amy Bartlett, LaTresha Garrison, Kristie Hagemo, Jennifer Mullaney, Ashlee Murfitt & Shelly Smith (1999): *Preservice teachers engaged in reflective classroom research*, The Teacher Educator, 34:4, 259-275
Link to: http://dx.doi.org/10.1080/08878739909555206

Steps in Action Research

Within all the definitions of action research, there are five phases of inquiry:

(1) Identification of problem area/question
(2) Collection and organisation of data
(3) Interpretation of data
(4) Action based on data
(5) Reflection

For most practitioners the first step is to formulate a plan/design. McNiff and Whithead (2005) call this reflective questioning and the 'Wh-?' questions deal with immediate practical issues: what? who? which? when? where? why? All of these 'Wh-' questions can be turned into a 'how do I…?' that will signal your intent towards improvement.

Developing a Research Question

Start with a "free write" activity based on these questions:
- What do I want to figure out? and why?
- What do I want to know about my teaching?
- What do I want to know about student learning?
- What classroom situation do I want to analyse?

Share highlights from the free write session and brainstorm with a colleague. A research question can take shape and evolve over time and it is advisable that you recast your questions several ways. Write your question first as a why statement:
- Why do my students do ...?
- Why do I do ...?

Next, recast your question:
- What happens when ...?
- How does ...?
- What is happening when ...?

Settle on a question that you feel comfortable addressing and then brainstorm ways that you can collect data that may address the question you have chosen. As you begin collecting data, you may discover that it will be necessary to revise your research question to fit the data. You may find yourself asking, "Is there something else more interesting emerging from my data?"

Review your research question by asking:
- What data do I have?
- What does the data tell me about my question?
- What other questions does my data tell me about?
- Is my question more complicated than I had previously thought?

You may need to revise or even change your question. However the research that you are doing is helping you become more aware of what is happening in your classroom.

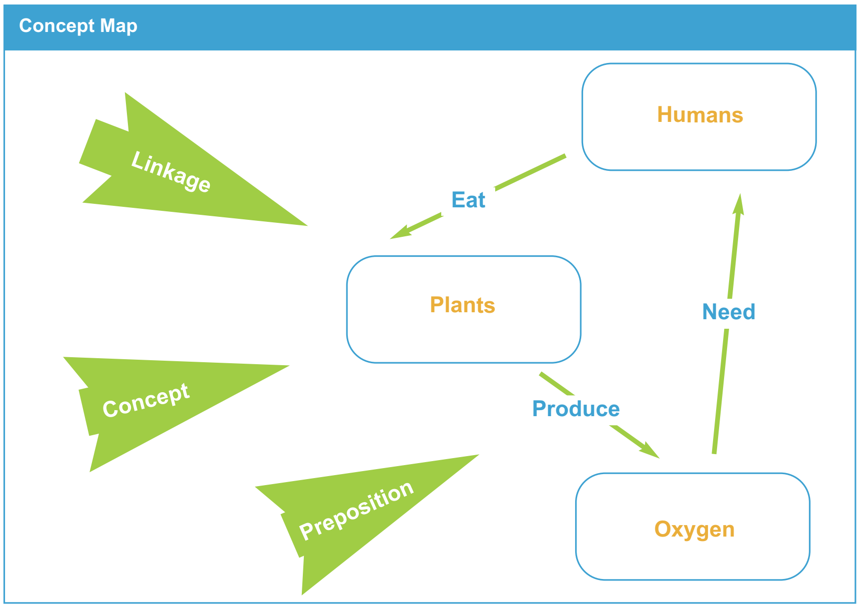
Framework for formative and summative assessment

These techniques may be considered to be assessment or evaluation strategies that you can use with your students to monitor their learning/progress. When utilised in action they are formative methods and when reflected upon after the event they may be used as a means of summative assessment.

1. Concept maps

A concept map is a visual representation of the links between mental concepts. This tool was invented to study changes in students understanding of science concepts in the early 1970s by Joseph Novak and colleagues. Research has shown that concept maps are reliable and valid indicators of conceptual understanding and changes in relevant concepts and propositional structures (Novak and Canas 2006). Not only are concept maps useful for assessing knowledge development, but they are also intended to help students understand how to learn meaningfully and co-operatively. The latter occurs when concept maps are constructed in small groups, where faulty ideas may be challlenged and corrected. An important function of concept maps in inquiry-based learning is to help make explicit the overall framework of the key concept. This is particularly important for complex topics where students display a fragmentary understanding of a topic and are frequently unable to integrate the components to form a meaningful overview (Kinchin & Hay 2000). Concept maps are therefore not only helpful to assess student development but to monitor the effects of inquiry-based science instructions.

Concept maps show the specific label (usually one or two words) for one concept in a bubbles or boxes, with lines showing linkage words that create a meaningful statement or proposition.



(adapted from www.plantscafe.net/modules/b_book_engl_ti_m19.pdf)

The use of concept maps for classroom/out of school learning assessment needs to include four subsequent steps.

(1) Create a master concept map first. This one is based on the knowledge content s/he expects students to develop in course of IBSE activity/unit. This master map can also be provided by another expert in the field, e.g. scientist.
(2) Students are trained in a concept mapping technique and they develop a level of proficiency necessary to produce a reliable result
(3) Time is allocated in the IBSE curriculum to produce concept maps
(4) The teachers/educator selects an adequate scoring technique to analyse the concept maps based on a given research/reflective practice question.

The concept map evaluation involves an examination of the content and the structure of a concept map. The nature of the analysis may involve qualitative and/or quantitative observations. Assessment tasks may include comparison of the scores from one assessment to another (Pre-and post-assessment). Research has shown that comparing students map with a master map leads to more valid results (McClure et al 1999).

Quantitative analysing techniques can simply focus on counting correct concepts, linkages and/or prepositions appearing in a students concept map in comparison with the master map. A map score is calculated for each student map. The most reliable but time consuming method is to define a neighbourhood for each concept (one concept and its direct neighbors). The concept neighborhoods in students' maps are then compared with the congruent concept neighborhoods in the master map and a similarity score is calculated. Finally all concept scores are added to a map score. A less time-consuming method with good reliability is the rational scoring method adapted from McClure and Bell 1990. Individual maps are scored by evaluating the separate prepositions identified on the map. A preposition is defined as two concepts connected by a labeled arrow indicating the relationship between the concepts. Each preposition is scored from 0-3 in accordance to the correctness of the preposition (the levels of correctness needs to be described in a scoring protocol) in comparison with the master map (McClure et al. 2000).

Concept Mapping as a Form of Student Assessment and Instruction

Read the paper outlining how concept maps may be used as a form of student assessment. There are many examples of concept maps – what do you envisage as the main advantages and disadvantages to incorporating this strategy into your teaching?
Link to: http://www.vanth.org/mmedia/vanth0103/vanth0103cd/papers/WalkerConceptMap02.pdf

A qualitative approach means that maps can be differentiated in terms of their complexity, resilience in accommodating additions, establishment of a context for the key concepts degree of a appreciation of a wider viewpoint and in relationship with a expert view (= master map). Different structures are: Spoke, Chain and Net. Implicit in this classification is the development of increasing integration of a conceptual framework from “Spoke” to “Net” (Kinchin & Hay 2000).

2. Concept Cartoons

Concept cartoons are cartoon-style drawings that put forward a range of viewpoints about a science concept or every day event. Naylor and Keogh (1999) developed, researched and refined their use as a science assessment and teaching tool. This strategy takes account of constructivist views of learning – taking students' ideas into account when planning teaching. By presenting a number of possible alternatives, "cognitive conflict" generates conditions for learning readiness. It also draws on research into common areas of misunderstanding in science.

Features of concept cartoons include:

- presentation of alternative ideas about a concept, including the scientifically acceptable stance;
- the use of images;
- minimal use of written language; and
- contexts that are familiar to children.

Concept cartoons can be used at the beginning or part way through a unit of work, to:
gain an indication of the range of students' ideas within the class;

- identify areas of misconception;
- stimulate starting points for investigations;
- offer challenges that may lead to restructuring of ideas.

They can also be used at the end of a unit of work to review learning. More details and examples can be viewed on the concept cartoons website (www.conceptcartoons.com).

Concept cartoons stimulate students to discuss their ideas, including those that are normally reluctant to do so. This gives teachers access to those ideas. It also gives students access to each other's ideas, which may prompt them to reconsider their own. The visual cartoons and minimal written text provide a valid assessment strategy for students with poor literacy skills, reluctant learners, and ESOL students. Concept cartoons appear to reduce the risk of fear of giving a "wrong" response.

How to use concept cartoons:

- Present the concept cartoon to individual students, small groups, or the class.
- Ask them to comment on each statement or ask them to indicate which statement they agree with.
- Ask students to give a reason for their choice. This is particularly important for accessing their thinking processes.

- Encourage debate between students with different opinions.
- Follow up discussions with students setting up investigations to explore their ideas.
- Note that for some concept cartoons there may be no one right answer. "It depends on…" may be an appropriate response.

To generate your own concept cartoon:

- Use everyday contexts that students are familiar with. Provide three or four different statements for discussion.
- Generally use positive rather than negative statements.
- Refer to research on common alternative conceptions as a source for statements.
- Include the scientifically acceptable viewpoint.
- Some multiple-choice questions are suitable for adapting to a concept cartoon.
- Instead of having faces, just use speech bubbles from the "Draw" feature of your word processing programme. This may be more appropriate for older students.

For examples of concept cartoons: http://plantscafe.net/modules/b_book_engl_t2_m11.pdf or click on the examples given at http://www.millgatehouse.co.uk/science/ccscd

Limitations of concept cartoons:

Teachers need to access research into common alternative ideas to construct their own concept cartoons. Cartoon faces or stances that are not carefully chosen may inadvertently provide clues.

3. Portfolios of evidence

Reflection and assessment are essential for learning. Gillespie et al (1996 p.487) define portfolio assessment as a purposeful, multidimensional process of collecting evidence that illustrates a student's accomplishments, efforts, and progress (utilizing a variety of authentic evidence) over time. What is collected; Who collects it; How it is collected; Who looks at it; How they look at it; and What they do with what they see are all determined first by the purpose for the portfolio. Portfolios can be used to show growth over time, to show progress towards curriculum standard, to show the journey of learning including process and products over time, as well as used to gather quantitative information for the purposes of assessment outside the classroom (e.g. Anson & Brown, 1991; Fritz, 2001; Millman, 1997; Willis, 2000).

The strengths of portfolios is the range and comprehensiveness of evidence, variety and flexibility in addressing its purpose (Julius, 2000). Portfolios are used successfully in different ways in different classrooms. Portfolios provide for a range of expression of learning and do so with evidence that can be of considerable technical quality and rigor.

From an assessment perspective, portfolios provide at least four potential "values-added" to more traditional means of generating evidence of learning:

- they are extensive over time and therefore reveal growth and development over time;
- they allow for more sustained engagement and therefore permit the examination of sustained effort and deeper performance;
- to the extent that choice is involved in the selection of content (both teacher and most especially student choice), then portfolios reveal students' understandings about and dispositions towards learning;
- they offer the opportunity for students to interact with and reflect upon their own work.

The emphasis in portfolio development could be on two different levels:

- On the process of the portfolio construction – this is a formative approach, where the emphasis of the professional development effort should center on the process of development;
- On the portfolio as a product – this suggests a summative approach, where comparison might be made between the finished portfolio of others.

Meta-cognitive skills are supported and practiced during the development of a portfolio as students reflect on their learning and select work samples, put work samples in the portfolio, and prepare self-assessments that explain the significance of each piece of work. Portfolio construction involves skills such as awareness of audience, awareness of personal learning needs, understanding of criteria of quality and the manner in which quality is revealed in their work and compilations of it, as well as the development of skills necessary to complete a task. Portfolios are used to support learning and for assessment purposes, both formative and summative. Portfolio assessment is linked to self-directed learning, since the onus is on the learner to demonstrate achievement of the appropriate standard. The portfolio provides a framework into which the learners can put self-selected material providing evidence of their achievements. Assessment must be focused on the learning outcomes of the curriculum. The attraction of the portfolio is that it can include evidence of achievement of all the learning outcomes within its structure.

Portfolio assessment has five stages:

(1) Collection of evidence of achievement of learning outcomes;
(2) Reflection on learning;
(3) Evaluation of evidence;
(4) Defence of evidence;
(5) Assessment decision.

4. Interviews

The interview is a widely used means of data collection and is central in most research designs. Interviews are purposeful conversations between the respondents and interviewer/researcher. Interviews are generally seen as an effective way of seeking people's views. How many interviews you plan to carry out is determined by reality, time and resources, but it also depends on the purpose of your interviews. As with all data collection, your design stages should include planning ahead to how the data will be analysed and interpreted to make sure that you have planned in time to review interview data and emerging issues as you go along and not leave it all until the end of your project. It is important that you are eliciting the responses you require for your research; if the interviews are not transcribed or reviewed until they have all been completed you may miss opportunities for clarifying key points as they emerge. The personal nature of interviews can be viewed as both as a strength and a limitation. The main advantages of interviews are that they can provide an opportunity for in-depth conversation with respondents (students, teachers, colleagues). They can yield rich data and are useful for gathering data from students. Questions may be clarified if necessary, which is not possible when using questionnaires. The main disadvantages are that they can be very time-consuming and the data is not easy to quantify. Also, if the interview/data was poorly planned, then the data may be difficult to analyse and the interviewer may unintentionally misrepresent findings. It is therefore important to spend time planning and testing your questions, to take time to build a rapport with respondents and consider recording the interview.

A first step in analysis is to read the transcripts from the interviews repeatedly (or to listen to the recordings several times). You might want to make notes, annotate as you go along. At this point you can begin to make notes about what you have learned from the interview and summarise these. The interview data can be analysed into broad categories/groups/themes (your research questions) to look for trends and reflections on the data. This means labeling segments of texts. You may wish to use mind-mapping to organise these labels into themes. It is important to be systematic and objective as you examine your data. Write up your major points and match collected data to each major point.

5. Observations

Observational techniques are an important aspect of many action research studies and case studies. An important question is: what specific contribution can observation make to research in education? What can observational techniques provide that concept maps or interviews cannot? The distinctive feature of observational techniques is their ability to record the flow of interaction, i.e. the dynamics of behaviour. There are a number of observational techniques available: simple check list, a structured observation schedule for classroom research, using videos, still photography, tape recorders, verbatim or selective field notes or memory, or a combination of one or more of these.

The difficulty with all these methods is that the problem of what to do with all the data collected. The data is certainly richer and more faithful to the nature of the interaction.

There are a number of issues with conducting observations:

- what to look at;
- how to observe;
- where and when to look;
- what to record.

Wolcott proposes four strategies for deciding what to look at and how to look:

- Observations by broad sweep – selectivity and what really matters to you.
- Observations of nothing in particular – wait and see what jumps out.
- Searching for paradoxes.
- Searching for the problem(s) facing the group.

Recording during observation should be carried out as unobtrusively as possible, ideally noting verbatim speech or at least some key words/phrases that will serve to jog the memory later. It is essential to constantly analyse and interpret data; or it may become so complex, convoluted and confusing that it is fails to serve any purpose.

Teacher training in IBSE at LFU, Austria

Part 3: The Kew INQUIRE course

Overview of the Kew INQUIRE course structure

The programme includes:

- 2 full contact days at Kew;
- 2 twilight sessions at Kew;
- 15 hours of self-study – aided by some directed assignments;
- A visit to the botanic garden where the course participant will deliver and assess an IBSE activity with their own class + post evaluation / reflection session;
- 15 hours for completion of a 'Portfolio of work' as a final assessment (across course duration or post course completion as agreed);
- A final plenary session.

This schedule offers an opportunity to spread the workload across a longer period, allows for seasonal variation and plant resource availability at the botanic garden and provides time for reflection, self-study and assessment of learning, as well as decreasing the impact on schools in terms of teacher cover for participants. Participants with long 'travel time' to Kew may be able to negotiate a slightly different pattern to the sessions / module locations offered. Dates and timings are set annually and reviewed throughout the course to offer, as far as possible, the optimum combination of dates and timings for participants.

Why educate about biodiversity conservation and climate change?

Climate change is one of the most critical issues facing us today and key to the mitigation of, and adaptation to, this increasing threat is our understanding of its impact and recognition of what actions we need to take. Understanding the nature and values of plant biodiversity is also vital to livelihoods as well as our physical and spiritual well being. Plants and fungi underpin everything that we do in our lives, providing such basic direct resources as food and drink, fuels, shelter, clothing, medicines and recreational resources such as books and musical instruments, as well as delivering ecosystem services such as cycling of nutrients and water, climate regulation, acting as flood defences and providing habitats for other biodiversity, including humans.

We are aware that there is a need to support the teaching and learning about climate change, plant biodiversity and the sustainable management of our natural resources, as up to date information and expertise are not easy to access. Additionally, over the last twenty years, formal education programmes in plant and fungal science have been largely ignored in contrast to animal/human biology, with the result that there is an extraordinary lack of knowledge and understanding about plants and the real impact that non-sustainable management of such organisms will have. Climate change and biodiversity are therefore the key topics used to deliver our INQUIRE course. Botanic gardens and similar organisations are ideally placed to provide information about, and demonstrations of, cutting edge science in plant /habitat conservation, knowledge of plant and fungal biodiversity and research into the sustainable use of plant resources. These are offered as enrichment sessions within the course.

Programme for the Kew INQUIRE course

INQUIRE Project Objectives: Participants will:

- develop an understanding of the advantages and disadvantages of using IBSE methodology;
- experience IBSE learning and usable resources in formal and informal settings;
- pilot and evaluate their own developed lesson at Kew Gardens/appropriate agreed site;
- have enrichment sessions, where appropriate, on biodiversity, conservation and climate change;
- provide evidence of an end of project assignment using a chosen presentation format.

During the course of the IBSE training, teachers and educationalists will be taken through the key understanding of variation and biodiversity, in contexts that will support the delivery of the national curriculum, enhance their subject knowledge on biodiversity and climate change and direct their teaching pedagogy to facilitate learning in and out of the classroom.

Dress Code: There is no formal dress code. However please note that sometimes we will be working across different parts of the Kew site and may be outside. Please make sure that you have comfortable footwear and wet weather/or appropriate seasonal clothing.

Course Resources: There is a dedicated website for INQUIRE participants for which each student will receive an individual registration and log-in number. As the course progresses, participants will be expected to use the web for resources and further course information. You will also be able to have your own resources/comments/blogs uploaded to the website. The course deadlines/programme of events and recommended reading will be published online on the course website. We suggest bringing a memory stick so that, if you wish, you can upload teaching sessions on the day. A number of published resources are available on site at Kew for course participants to use.

Assignments/Final assignment: A post-module assignment will be set after each contact session at Kew/Botanic Garden site. We would appreciate work being submitted by the date agreed. Final projects, focusing on inquiry-based learning for a sustainable future, should be presented as a portfolio of work and include individual reflections and findings. It should contain your own assessment of the impact the course has had, if any, on your teaching delivery and the impact on the students you have been working with over the duration of the course. The portfolio can be developed using a range of media. However if a written assignment is produced, the word count should be no more than 5000 (excluding the lesson plans). Many of the resources, discussion pieces and comments produced in the individual assignments that are completed over the length of the course and in personal study time, will provide good materials for inclusion in the final portfolio of evidence. Please remember to collate this material and add it to your portfolio as the course progresses.

Plenary: This course is also being run at the Royal Botanic Gardens, Edinburgh and it is hoped that there will be opportunities for interaction between participants on the Kew and Edinburgh courses. This may take place via video link-up or by a joint plenary session at a site agreed by both parties.

'CO2 in the world: production and absorbtion' activity at NBGB, Belgium

Module 1: IBSE explained. Kew Gardens, Museum No.1

Time	Activity	Notes	Post Module Assignment
9.30-9.45	Coffee/Welcome/H&S		1. What questions do you have about IBSE? 2. Reflect on one activity of Day 1 of IBSE course 3. Develop IBSE activity of your own and write lesson plan
9.45-10.45	Decomposition activity	Group activity	
10.15-11.00	IBSE questioning exercise: What does IBSE questioning look like?	Work in pairs	
11.15-12.15	Theory/Concept of IBSE	Powerpoint & Discussion	
12.25-12.30	Setting of first post-module assignment GB		
12.30-1.15	Lunch		
1.15-2.45	Carousel to explore ‘Theory of Inquiry’ to include set of activities and video clips	Concept cartoons ‘Vegetable Ident’ activity; Diamond Nines; Ethical matrix; Lets Talk/ Rational Food clips	
2.45-4.15	Activity: ‘What is a flower?’	1. Observation & research in BG 2. Plant material investigation in Lab Two questions to be completed in this section. Work individually, in pairs or threes. Bring outdoor clothes	
4.15	Recap on assignment; Q&A; Administration, etc		
4.30	Close		

Module 2: Exploring Biodiversity & Conservation tactics. Kew Gardens, Museum No.1

Time	Activity	Notes	Post Module Assignment
9.30-9.45	Coffee/Welcome		Reflect on how incorporating IBSE into your lesson plans would change the learning and/or experiences for each student in the class Using the same strategy implement this or any other lesson with your class. Reflect on effectiveness & impact Submit evidence that you completed this exercise, plus reflections on what you changed, implementation process & impact
9.45-10.45	Review of 1st post-module assignment & self-study	Discussion on questions & reflections generated by participants	
10.45-12.30	'Your Choice, Your Future' SH	In pairs. Activity in Princess of Wales Conservatory & Museum No.1	
12.30-1.00	Lunch		
1.15-3.00	"Ecology in Action'	Work in teams in field study zone. Bring outdoor clothes	
3.00-3.45	Visit Herbarium/Meet a Scientist		
3.45-4.25	Micropropagation activity		
4.25-4.30	Setting of 1st post-module assignment GB		
4.30	Close		

INQUIRE

Twilight Sessions 1&2

Time	Activity	Notes	Post Module Assignment
4.30pm-7.00pm	Sharing activities that have been developed and trialled	Presentations by participants and discussion on what went right & what went wrong	In preparation for planned school class visit, participants must submit a lesson plan for their activity & risk assessment
7.00-7.30	Optional visit to Jodrell Laboratory		
7.30	Close		

Leading effective LOtC in IBSE – activity visit by school group & evaluation session

Time	Activity	Notes	Assignment
10.30-2.30pm	INQUIRE participants lead school visit to botanic garden. Students to complete on-site IBSE investigation	Assessment by Tutors	Final portfolio submission
Post-visit (2hrs)	Evaluation of visit & activity	At school or participant Botanic Garden site	

Final plenary

Time	Activity	Notes
3 hrs	Reflections and sharing with Edinburgh Participants	Video link or Site meeting Evaluation of course; IBSE delivery & portfolio production

Additional notes

- A number of resources will be available for use during the duration of the course. Participants may borrow reading material to take off site with the permission of the tutor.
- Participants will be able to download any information or course papers from the INQUIRE website or during the visits to Kew.
- There are many criteria that can show an IBSE approach to an activity, however not all criteria will be present in all IBSE activities. During the course, participants might find it useful to reflect on the IBSE criteria in each of the activities they participate in or in activities they develop. To support this Kew has developed an IBSE Criteria Checklist , which is shown below. Please note that this list is not exhaustive.
- INQUIRE course providers rely on teachers to follow their school H&S guidelines when participating with their students in the INQUIRE course. Kew works under a strict Health and Safety Code ; all Inquire course activities will be risk assessed and course participants will be advised of any H&S issues prior to arrival and / or prior to taking part in activities. For more information on School visits to Kew please see the Kew Website pages on http://www.kew.org/learn/schools/school-visits/kew-gardens/index.htm .To download the Health and Safety notes and Generic Risk Assessment Forms please see page http://www.kew.org/learn/schools/school-visits/kew-gardens/most-of-your-visit/health-safety/Learn---Schools---Make-Most---H&S.htm
- The INQUIRE website (www.inquirebotany.org) is the main communication platform for teachers and educators who participate in the INQUIRE courses but is also relevant to wider audiences throughout Europe. The INQUIRE website is complemented by other social media such as Facebook, twitter, YouTube, Flickr. All these tools aim to support the development of a community of practice in IBSE through which people come together to collaborate, learn and build knowledge. Details of the resources available on the website can be found in Appendix 2.

Inquiry-Based Science Education (IBSE)

(Inquiry = investigate/examine/inquire/inspect/study/look into/explore/consider/scrutinise/probe)

Inquiry-based learning is aimed at facilitating understanding rather than rote based learning of facts, e.g. multiplication tables/names of planets etc. Facts and core concepts are brought together to develop knowledge and understanding. Activities can be IBSE assessed by checking how many IBSE criteria they integrate. For each activity tick the IBSE criteria which are included.

Inquiry-Based Science Education (IBSE)

IBSE Criteria	Activity Title	Activity Title	Actvity Title	Activity Title
Deepen fundamental understanding				
Develop personal scientific confidence				
Become independent learners				
Build upon unrelated prior knowledge				
Apply knowledge in unfamiliar contexts				
Analyse and problem-solve				
Think creatively and laterally				
Develop scientific procedural skills				
Develop a desire to learn				
Become aware of 'how science 'works'				
Investigate career interests				
Test hypotheses				
Reflective practice				
Work forward from negative result				
Develop social skills				
Develop communication skills				
Score (number of ticks)				

Inquiry tasks should also include and consider:

- hands-on work;
- group work;
- appropriately set for level of students and differentiated for abilities and disabilities;
- easily set up with available and inexpensive resources;
- giving sufficient time for some or all of the following; prediction, carrying out, reflection, development, conclusions and communication.

Student investigations at MUSE, Italy

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Student inquiry at SBZH, Germany

Appendices

Appendix 1 – IBSE in the National and European Context

IBSE in the national context

Science education in the United Kingdom has involved both theoretical study and practical work for more than a century. What counts as practical work, though, has varied over time and, since the 1980s, students have been encouraged to develop scientific skills through activities that involve designing experiments, carrying them out and evaluating the outcomes. The term 'investigations' was commonly used in the 1990s to describe activities which some people argued helped students to 'be a scientist'. Others argued that such an outcome was unrealistic and simplistic. With the advent of the National Curriculum in England and Wales in the late 1980s, scientific inquiry by students was mandated and assessed systematically if not necessarily validly. Over the last 20 years there has been renewed focus on promoting practical work as it has been thought that the amount of scientific inquiry has diminished. A more recent focus has been on the quality of practical activity and on the need to match scientific inquiry with the development of both practical skills and deeper understanding of scientific concepts. The quality of scientific inquiry practiced in schools in the UK remains highly variable and partly depends on teachers' views of the nature of science and on the value that they put into using an inquiry-based approach in their teaching.

IBSE projects at the national level

Projects related to IBSE are usually implemented at the EU level (see below) and are currently not developed within the context of National Curricula of UK countries. Notwithstanding this, inquiry-based learning is a recognised pedagogy and is used by some teachers (see comments above) and across a range of disciplines. Many of the large IBSE EU projects have key UK educational partners who have a wealth of experience and who are recognised authorities on science education delivery, including such institutes as King's College, London, the Universities of Bristol and Bath and the Institute of Education, London among others.

IBSE projects in Europe

The 'Science in society' initiative aims to stimulate a harmonious integration of scientific and technological endeavor and associated research policies in European society. "Young people and science" is one out of several activities to reach this goal. The Innovation Union Communication recognises that weaknesses remain with science teaching and support activities that include "Inquiry Based Science Education" (IBSE) as defined in the "Science Education Now; A renewed Pedagogy for the Future Europe" (Rocard, 2007) report. There are currently several Education projects running in FP 7, Science and Society and this funding stream will be continued in FP 8. In addition, the Lifelong Learning Program funds science education activities too. Some of these projects are listed below.

Selection of FP6, FP7 & Lifelong Learning projects (2011) [A]

Acronym	Name	Website
METAFORA	Learning to learn together: a visual laguage for social orchestration of educational activities	**www.metafora-project.org**
PRIMAS	To promote inquiry-based mathematics and science at primary and secondary levels across Europe	**www.primas-project.eu**
SED	Science Education for Diversity	**www.www.marchmont.ac.uk/projects/detailpage.asp?MarchmontProjectID=26**
SEEP	Science Education European Platform	**www.seepnetwork.eu**
ESTABLISH	European Science and Technology in Action	**www.establish-fp7.eu**
TRACES	Transformative Research Activites, Cultural Diversites and Education in Science	**www.traces-project.eu**
PROFILES	Professional Reflection -Oriented Focus on Inquiry -based Learning and Education through Science	**www.profiles-project.eu/**
S-TEAM	Firing-up science education	**www.s-teamproject.eu**
PATHWAY	The pathway to inquiry -based teaching	**www.pathway-project.eu**
SCHOOLSCIENCE.CO.UK	Resources and news for science education	**www.schoolscience.co.uk**
FIBONACCI	The Fibonacci project	**www.fibonacci-project.eu/**

Selection of FP6, FP7 & Lifelong Learning projects (2011) [B]

Acronym	Name	Website
EU-HOU	Hands-on Universe	www.handsonuniverse.org/
COMPASS	Common problem-solving strategies as links between mathematics and science	http://compass.ph-freiburg.de/
SCETGO	Science Centre to Go	www.sctg.eu/
PHOTONICS EXPLORER	Photonics Explorer	www.photonicsexplorer.eu/
EUNAWE	Inspring every child with our wonderful cosmos	www.unawe.org/
SCIENCE ON STAGE	Science on stage	www.scienceonstage.at/
DYNALEARN	The Dyna Learn Project	http://hcs.science.uva.nl/projects/DynaLearn/
POLLEN	Seed cities for science education	www.le.ac.uk/slcem/topics/pollen.html
CARBOSCHOOLS	The CarboSchools project	www.carboeurope.org/education/
EBUG	eBUG project	www.e-bug.eu/
COREFLECT	Digital support for Inquiry, Collaboration and Reflection on Socio-Scientific Debates	www.coreflect.org/nqcontent.cfm?a_id=3689
FORM IT	Form-it-Take Part in Research	www.form-it.eu/
PLASCIGARDEN	Plant Science Gardens	www.plantscafe.net/

POLLEN **(www.pollen-europa.net/)** promoted science teaching renovation based on inquiry approach in primary schools. A network of "Seed Cities" illustrated how teaching can be reformed at a local level within schools whilst involving the community.

Creative Little Scientists **(www.creative-little-scientists.eu/)** aims to bring together creativity, science and mathematics in preschool and first years of primary education. The project proposes guidelines, curricula and exemplary materials for relevant teacher training in the various European contexts.

SiS Catalyst **(www.siscatalyst.eu/)** is an initiative to foster and support ethical, effective and sustainable engagement between children aged 7-14 years and the social, cultural, political, scientific and educational institutions which make the decisions that will shape their futures.

The CarboSchools project **(www.carboeurope.org/education/)** is a collaboration of science researchers and secondary school teachers who invite young people to learn about local and global impacts of climate change, explore scientific research on the topic and act locally to reduce emissions of greenhouse gases.

STENCIL project **(www.stencil-science.eu/)** has established a networking platform for science teachers and educators to encourage joint reflection and European co-operation. STENCIL promotes innovative practices by publishing an Annual Report, and organising study visits and workshops.

COMPASS **(www.compass-project.eu/)** aims to support teachers to develop lessons that connect science and mathematics with each other and with the lives of their students. The project promotes common problem solving strategies as links between mathematics and science.

Project CoReflect **(www.coreflect.org)** brings together multi-disciplinary teams of researchers, educational authorities and teachers to develop digital, web-based inquiry learning environments to facilitate students working on science-related, project-based investigations.

ESTABLISH **(www.establish-fp7.eu/)** facilitates and implements an inquiry-based approach to science education for secondary level students. The project has developed teaching and learning materials and provides support to in-service and pre-service teachers through professional development.

The Fibonacci Project **(www.fibonacci-project.eu/)** aims at a wide dissemmination of inquiry-based science and mathematics education (IBSME) in Europe, through the establishment of reference centres that have an expertise in the implementation of sustainable inquiry-based Science and/or mathematics education.

The overall aim of **Form-it** **(www.form-it.eu/)** is to promote the interest of young people in science and to qualify them for a critical and complex way of thinking and learning. Form-it has brought together academics and practitioners, and increased awareness for excellence in science education.

The aim of the **PATHWAY project** **(www.pathway-project.eu/)** is to facilitate the development of communities of practitioners of inquiry that will enable teachers to learn from each other. PATHWAY disseminates methods and exemplary cases of both effective introduction of inquiry to science classrooms and professional development programmes.

Plant Science Gardens **(www.plantscafe.net/)** was a project that developed inquiry-based activities focussed on plants – their growth, their importance economically and culturally and the need for their conservation.

PRIMAS **(www.primas-project.eu/)** aims to effect change across Europe in the teaching and learning of mathematics and science by supporting teachers to develop inquiry-based learning pedagogies. The project provides IBSE resources, runs professional development activities and support professional networks in each of the partner countries.

PROFILES **(www.profiles-project.eu/)** promotes IBSE through working with teacher partnerships to implement existing, exemplary IBSE focussed, science teaching materials enhanced by inspired, teacher relevant training and intervention programmes.

Science on Stage **(http://scienceonstage.eu/)** is a European initiative designed to encourage teachers from across Europe to share best practice in science teaching through running a science festival, workshops, teacher training courses and offering travel scholarships for teacher-exchange programmes).

S-TEAM **(www.s-teamproject.eu/)** aims to enable large numbers of teachers to adopt inquiry-based and other proven methods for more effective science teaching by providing training in, and access to, innovative methods and research-based knowledge.

TRACES **(www.traces-project.eu/)** investigated the factors contributing to the gap between science education research and actual teaching practice, and identified innovative policies in science education

Appendix 2 – The INQUIRE website and social media

The INQUIRE website (**www.inquirebotany.org**) contains news, resources, discussions, polls and information about the INQUIRE courses. Published in 10 languages, the website also encourages interactive dialogue. Our aim is to develop communities of practice in IBSE in 11 countries where learning extends beyond the attendance of the IBSE sessions run by the botanic gardens.

Most areas of the website are open access and, as a course participant, your details will be entered into the Content Management System of the website allowing you to view all areas of the website and to comment on resources, news and discussions. You can also sign up for the INQUIRE e-newsletter which is published three times per year. On the course pages you will find out which sites in your country are running INQUIRE courses, together with an overview and details about each course. Also on the course page is a poll. Every month we set up a new poll to provide a snap-shot of what teachers and educators think about a particular subject or issue.

For any enquires you can contact your course administrator through the website's Contact us page.

The website gives you also access to Facebook, Twitter and YouTube. Facebook is a social online networking service and has more than 800 million active users (LA Times, 2011). If you have a Facebook account we invite you to 'like' our INQUIRE page and post comments on our wall. Twitter is a social online networking and micro-blogging service and has over 300 million users (BBC, 2011). You can send and post texts (known as 'tweets') of up to 140 characters. If you have a Twitter account please follow us at: www.twitter.com/INQUIREBOTANY

IBSE as a pedagogy is aiming to empower the students to construct their own knowledge through inquiry. As a teacher or educator attending the INQUIRE courses you are encouraged to use the social media to take responsibility for your own learning and become co-producer rather than passive consumer of content. The use of social media in the INQUIRE project goes beyond the provision of viewable/downloadable content to enabling you to actively contribute and shape the content. You are encouraged to comment on the news and discussions, share your opinion on the resources uploaded on the website, but also raise issues related to IBSE using twitter and Facebook. Social media are offered for free, are easily accessible and promote dialogue through quick and easy publication and rapid feedback.

> *"Social web tools do appear to provide an architecture that can be used to promote active engagement students find useful and satisfying."*
> (Horizon, 2007)

INQUIRE

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