Implementing inquiry-based learning in science education (IBSE)

Wynne Harlen, presentation on September 22nd 2010

Introduction

The aim in this short presentation is to consider first the broad meaning of IBSE and a framework to represent how understanding in science is developed through inquiry skills. The implications of this process for students' learning experiences and for what teachers need to do and provide are then outlined, constituting a considerable challenge for professional development.

A broad meaning of IBSE

The aim of inquiry-based education in science is for students to develop their *understanding* in science through their own mental and physical activity. The Fibonacci Starting Package describes IBSE as aiming to ensure that 'students truly understand what they are learning and not simply learn to repeat content and information' (p1).

For any learners, real understanding can only be achieved through their own mental activity, for it is only when ideas make sense to them that they can use them in explaining objects, phenomena and events in the world around. We know this from our own experience. We also know, from research, that students make sense of the phenomena and events they encounter for themselves, but the understanding they arrive at may not be the same as that arrived at through a scientific approach. For example, students often have their own explanations for how we see, how plants feed and grow, why the Moon changes shape, etc. These ideas are often different from the scientific view. Research shows that, if these ideas go unchallenged, they can interfere with the development of more scientific understanding. But this understanding must be developed through the students' own activity. Hence descriptions of IBSE often spell out the processes involved. For instance:

> 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… identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations[1].

This list indicates that there is more to inquiry than 'hands on' experience. This becomes clearer as we consider how skills and experiences of different kinds combine in the progressive development of understanding of scientific ideas.

A model of learning science through inquiry

For anyone, trying to make sense of phenomena or solve problems starts from the ideas they already have. So the first step in the model is creating a possible explanation (hypothesis) through linking to existing ideas (Figure 1).

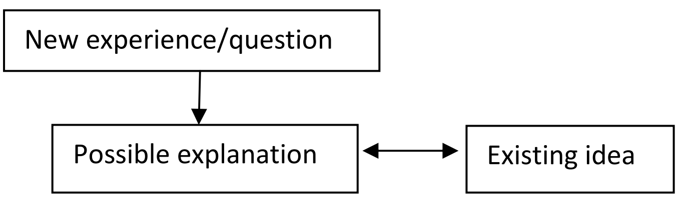

Figure 1

[1] NRC (National Research Council) (1996) *National Science Education Standards.* Washington DC: National Academy Press p23

Scientists and others working scientifically then proceed to see how useful these existing ideas are by making a prediction based on the hypothesis, because only if ideas have predictive power are they valid. To test the prediction new evidence about the phenomenon or problem is gathered, then analysed and the outcome compared with the predicted result. More than one prediction and test is desirable (figure 2).

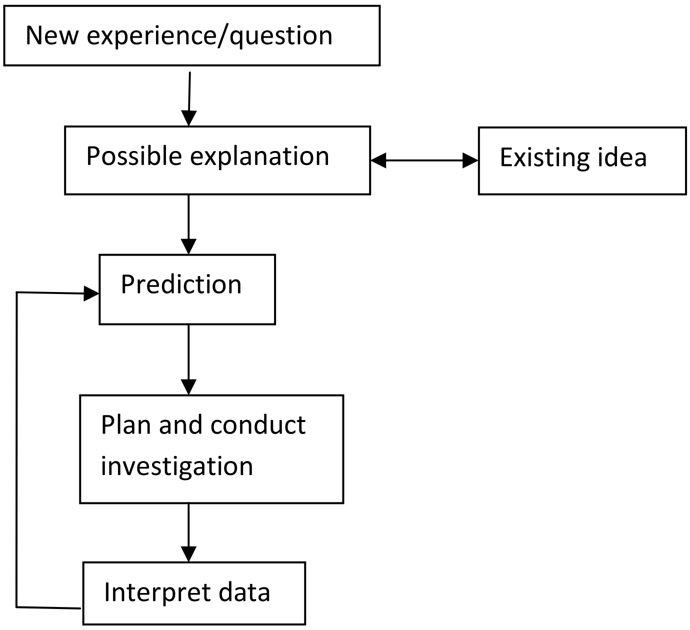

Figure 2

From these results a tentative conclusion can be drawn about the initial idea. If it gave a good explanation then it is not only confirmed, but becomes more powerful – 'bigger'. If not then a different idea need to be tried (figure 3). However, knowing that the existing idea does not fit is also useful.

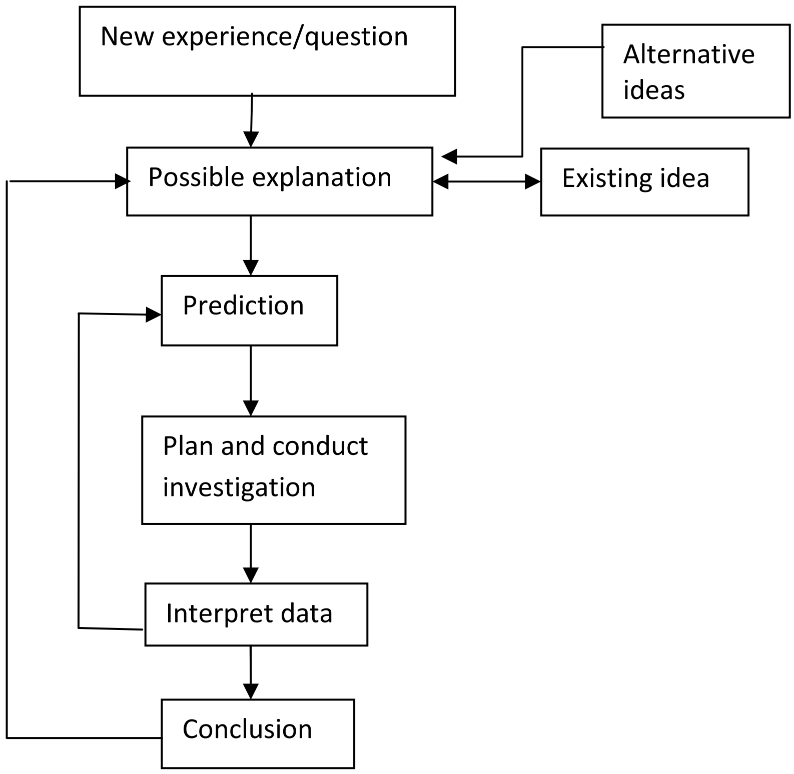

Figure 3

This is the process of building understanding through collecting evidence to test possible explanations in a scientific manner, which we describe as scientific inquiry. It is a simplified version of the framework which can be found in the Fibonacci Starting *Package Implementing Inquiry-based Science Education* (page 3).

However, students, particularly young students, do not instinctively use this process. They may not test their initial ideas and when they do they may not do it scientifically. They may predict what they already know; they may focus only on evidence that confirms their idea but ignore conflicting evidence etc. When these things happen, the ideas that emerge are not consistent with evidence: hence the importance of helping them to develop the skills of scientific inquiry. In doing so, it is important to acknowledge, and to start from, the ideas the students already have, for if these are just put aside the students will still hold onto them because these are the ones that they worked out for themselves. They must be given opportunities to see for themselves which ideas are more consistent with evidence. Thus a **constructivist pedagogy** is implicit in this view of inquiry. This means:

- helping students to understanding phenomena in a more scientific way, starting from the ideas that students bring from their previous experience
- enabling students to take an active part in creating their scientific understanding
- helping them to consider alternative ideas to their own through access to resources and discussion with others
- engaging them in discussion, sharing, dialogue, defending and reflecting on their ideas.

Similarly this view of inquiry implies much that is involved in **formative assessment,** sharing the aim of developing understanding through learners taking charge of their learning. The formative use of assessment is a continuing cyclic process in which information about pupils' 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. Taking charge of their learning 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.

What ideas?

Before moving onto implications for students' learning and teachers' activities, it is important to emphasise that the aim of IBSE is the understanding of key ideas in science. The model in Figure 3 indicates how smaller ideas are progressively developed into big ideas. In this context a 'big' idea in science is one that applies to a range of related objects or phenomena, whilst what we might call smaller ideas applies to particular observations or experiences. Through science education, students should develop understanding of big ideas about objects, phenomena, materials and relationships in the natural world (for instance, that all matter is made of small particles; that objects are able to affect others at a distance). These ideas not only provide explanations of observations and answers to questions that arise in everyday life but enable the prediction of previously unobserved phenomena.

Science education should also develop big ideas about scientific inquiry, reasoning and methods of working (for instance, that scientific inquiry entails making predictions based on possible explanations and assessing the value of different ideas in relation to evidence) and ideas about the relationship between science, technology, society and the environment (for instance, that applications of science can have both positive and negative social, economic and environmental effects)[2].

Students should also develop scientific attitudes and willingness to take part in scientific activities, that is, to inquire and investigate in a scientific way. Goals of science education should include willingness to collect data in a controlled and systematic way, to be open-minded in interpretation of data, to work collaboratively with others, to be questioning and appropriately critical of claims and proposed explanations and, in the course of inquiries, to behave responsibly in relation to the environment and one's own and others' safety and welfare.

What this means for students' opportunities for learning

Bringing these points together means that students' activities should provide opportunities for

- developing skills of questioning, observing, measuring, hypothesising, predicting, planning controlled investigations, interpreting data, drawing conclusions, reporting findings, reflecting self-critically on procedures
- working collaboratively with others, considering others' ideas and sharing their own
- expressing themselves using appropriate scientific terms and representations
- developing understanding of ideas that progressively lead to the big ideas that help them to understand scientific phenomena in the world around
- applying their learning in real-life contexts.

What it means for teachers

For students to have these opportunities and to develop the skills, ideas and attitudes it follows that teachers activities should include:

- encouraging, through appropriate questioning, the use of inquiry skills in testing ideas
- probing students' ideas and skills by questioning, observing, and listening during the course of activities
- ensuring access to a range of sources of information and ideas relating to their science activities
- providing feedback that helps students to see how to improve or move on
- modelling scientific attitudes
- arranging regular group and whole-class discussions where scientific ideas and ideas about science are shared
- using information about on-going progress to adjust the pace and challenge of activities
- providing opportunities for students to reflect on their learning processes and outcomes.

Further, all this needs to be through activities that students find engaging, interesting and worthwhile. The choice of activities should

- enable students to develop understanding of key ideas in and about science
- concern real things in their experience that students see as relevant and appealing
- build on their previous experience and pre-existing ideas, providing challenges within the reach of students so that they experience pleasure in learning
- engage the emotions by making learning science exciting.

[2] Harlen (Ed) 2010 *Principles and Big Ideas in Science Education*.

The challenge for implementation of IBSE

Where teachers' practice is largely traditional and some way from fitting the descriptions above, making changes presents a considerable challenge for professional development. According to an IAP report[3] on professional development for IBSE, this should enable teachers to:

- develop a vision of effective inquiry in action through first-hand experience, cooperative group work and the study of good examples
- experience at their own level using inquiry skills and conducting different forms of inquiry
- develop their own content knowledge through inquiry and through access to written and on-line sources and to scientists
- acquire a deep understanding of how learning takes place and of their role in students' learning through inquiry
- know how to 'handle' students' questions and to be comfortable with not knowing the answers to all their questions
- use their environment, to connect science to other subjects, to make activities relevant to students' lives and, as appropriate, to blend scientific knowledge with indigenous knowledge
- develop the use of formative assessment and the use of their own assessment of students' progress in scientific skills, concepts and attitudes.

This represents a considerable challenge but one that the Fibonacci project, through international collaboration in sharing expertise, is well structured to address.

[3] Harlen and Allende (Eds) (2009) *Report of the Working Group on Teacher Professional Development in Pre-Secondary School IBSE.* http://www.interacademies.net/File.aspx?id=10428