Project I: Developing inquiry based learning in science
(Stockholm Institute of Education)

The idea of inquiry based learning (IBL) originally stems from the work of John Dewey (1910/1997) and Schwab (1966). An IBL situation is one where hands-on experiences should not be illustrations of theory already learnt, but be a continuous part in teaching, where students constantly should be negotiating and arguing about the relations between the natural phenomena and the ideas of science. IBL should also be seen as opposed to directed learning situations, where the problem and procedures are set and the students only have to produce the answer. Inquiry learning is also meant to be an inquiry into inquiry, where the procedures of science should be discussed and developed in the classroom (Schwartz, Lederman, & Crawford, 2004). This means that the aim of IBL is not simply to learn scientific facts and concepts, but also to learn about the nature of science (NOS) and inquiry skills (IS). The aim of IBL is closely connected to ambitions of enhancing scientific literacy.

Inquiry learning is now used in curricula world wide (Beeth et al., 2003). The conception of inquiry learning fits well into the ideas of a modern society where individuals actively and creatively construct knowledge. It is science education in an era when the rhetoric plays down reproducing and copying and instead advocates innovation as the goal for learning. Science is not taken as an unchangeable edifice, but is construed as critical examination. According to the US National Science Education Standards (National Research Council, 1996)

> inquiry is a multifaceted activity that 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. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations. (p. 23)

In many other parts of the world numerous projects have been implemented, and similar goals can be found also in science syllabi in Sweden. An international workshop in Stockholm, 2005, arranged by the InterAcademy Panel on International Issues (IAP, a network of National Science Academies of the world) on IBL programmes, attracted representatives of 28 nations from all continents, which is evidence of the expectations science communities world-wide have on IBL. In Sweden, the Royal Academy of Sciences and the Royal Academy of Engineering Sciences currently together with more than 60 municipalities are introducing inquiry learning units into Swedish schools through the school programme NTA (Naturvetenskap och teknik för alla: Science and Technology for All).

Despite the enormous efforts and money put into inquiry learning projects, little examination has been made of what happens when they are put in use (InterAcademy Panel Workshop, 2005). The few studies available have mainly documented their output.
by giving students paper and pencil tests (e.g. McCarthy, 2005) or by measuring attitudes (Gibson & Chase, 2002). Results from paper and pencil tests of cognitive gains are usually equivocal. However, it is well known that both teachers and students need substantial support and learning to adopt new approaches efficiently (Supovitz & Turner, 2000; Abd-El-Khalick & Lederman, 2000). This suggests that studies are needed to examine what actually happens in classrooms when teachers and students adopt the new inquiry ideas in the classroom (Keys & Bryan, 2001). It is also important to develop the assessment procedures of learning and remembering of science knowledge in manners that are more relevant for IBL and that focus on generative skills such as the ability to adopt and reason in scientifically relevant ways. With such knowledge more effective support for teachers in using inquiry based science themes can be developed. We will especially focus upon such aspects that could be used to develop inservice training of science teachers in elementary school. Better knowledge of these matters would also be of interest to science educationists internationally, especially since our study is made in such diverse cultural settings.

The project on IBL has two phases. The first phase, to be focussed during years 2007-2009, will explore the following overarching question:

- How can teachers’ work with implementing inquiry skills (IS) and developing the ambitions to provide productive understandings of the nature of science (NOS) in Swedish schools be promoted?

In order to address this general issue, the following preliminary, to some extent descriptive, questions have to be answered:

a) How do teachers today work with implementing IS and NOS?
b) What do teachers know about NOS and IS?
c) What do students learn about NOS och IS as these are presently implemented?
d) What goals are realistic when it comes to implementing NOS och IS? What does the literature say on these issues?

Based on the answers to these questions, instruments that serve as formative evaluation regarding how NOS and IS are implement will be designed in co-operation with teachers. The instruments will serve not only the purpose of evaluating students’ learning, and how this learning can be supported, but they will also be designed to support teachers’ reflections on the teaching and its progress. The idea is that the evaluation instruments will not only be written questionnaires, but we will also seek to provide in-service training activities that support the implementation process. This latter work will be done in the context of the big project NTA (Naturvetenskap och teknik för alla: Science and Technology for All) briefly described above. This co-operation with the nationwide NTA project will be at the core of this work.

**Aims and methods**

The aim of this study is to investigate how teachers’ abilities to support pupils in their development of skills relevant for inquiry based learning can be developed. This will be done by designing an evaluation instrument with a focus on students’ knowledge and
skills to carry out investigations/inquiries and their understanding of natural science as an activity. The study will be implemented in the context of the extensive school development program NTA and it will include various kinds of in-service training activities.

The concrete steps in the research will be as follows:

a-b) Interviews and classroom observations of teachers with different experiences and backgrounds when it comes to teaching in natural science. A group of about 15 teachers will be selected for this step. The group will be selected from communities in the Stockholm area and in the county of Dalecarlia. All of these teachers work at schools participating in NTA at the primary and secondary school level.

c) Selection of classes based on the results of steps a-b. Further interviews and classroom observations in these classes.

d) A careful scrutiny of the literature with respect to results regarding attempts to implement IBL and NOS.

The classroom studies will be implemented in accordance with methods that we have used previously in other studies (cf., e.g., Wickman and Östman 2002). The focus is on student learning activities, and on the development of their understanding and retention of scientific reasoning and scientific work procedures.

A further step in this research process implies a selection of one model school. In cooperation with the teachers of this school the in-service training activities are implemented and the evaluation instruments are developed in relation to specific scientific themes for different age groups of students. The contents of the evaluation instruments are decided upon at the beginning of each theme while considering the outcome of the earlier phases of the research. During this step, a continuous documentation of how teachers understand and use the evaluation instruments as part of their practices will be implemented. When a particular theme has been finished, the instrument can be tested with other teachers in other schools.

A baseline for this work is the different evaluation instruments and procedures that have been developed by Professor Norman Lederman and his group at Illinois Institute of Education (cf. Flick & Lederman, 2004; Lederman & Niess, 1997; Hodson, 1999). These instruments have been used in developmental work and research in many contexts.

The second phase of this implementation of IBL and NOS will be carried out in 2009-2011 (years three to five of this program) This project will be a straightforward evaluation of the knowledge and skills acquired in IBL-classrooms in comparison to traditional forms of directed learning in science. The focus here will be equally on learning and on memory, especially long-term retention of scientific knowing. This will be a pre- and post test study between different classroom with similar resources in terms of teacher experiences and other factors. The pre- and post tests will be directed towards specific subject knowledge areas in mechanics in physics teaching. This comparison will
be carried out in Grade 8 and will involve a comparison of six lectures in mechanics (a core topic of physics teaching):

Five classes will be taught in accordance with the IBL model
Five classes will have traditional, directed instruction
A possible addition may be had from five classes using other, maybe mixed, approaches to teaching mechanics.

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<tr>
<th>Activity</th>
<th>Independent variable</th>
<th>Dependent variable</th>
<th>Dependent variable</th>
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<tbody>
<tr>
<td>Pre-test of knowledge in domain</td>
<td>Group 1. Teaching through IBL</td>
<td>Post-test of knowledge and skills</td>
<td>Analysis of classroom interaction and practices of learning and remembering</td>
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<td>Group 2. Traditional, directed teaching</td>
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<td>Group 3. Mixed approaches</td>
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This will be an ecologically relevant comparison of the uses of IBL and the consequences for learning. The details of this study will be formulated in due course and as a result of what is learned during the first phase.

The scholars responsible this project are Wickman, Bonäs and Johansson. This work is carried out in co-operation with NTA (Science and technology for all initiative) (www.nta.nu). As we have already hinted at, many sponsors are involved in this extensive program, among others Ljungbergsfonden and the Wallenberg foundation. Ljungbergsfonden is also funding one doctoral position that will be involved in this work. This position is held by Anni-Maj Johansson, junior lecturer at the University College of Dalarna, who will write her Ph. D. within this project.

All this research on IBL is a joint activity with Professor Lederman and his research team at the Department of Mathematics and Science Education, Illinois Institute of Technology, Chicago.