Inquiry Learning in STEM subjects

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A socio-cultural approach to Inquiry Based Education

How to implement Inquiry Learning?

From Open to Guided Inquiry

The teachers as a companion and a guide

Inquiry vers. research
Science Education has traditionally been assigned the role of transmitting knowledge. However, over the past 50 years, there have been dynamic changes in our conceptualisation of science learning and of science learning environments, integrating concepts such as ‘situated learning’ or the ‘socio-cultural perspective of learning’. 
These changes have important implications for how we interpret the role of inquiry in school science education programmes as well as curriculum development, teaching practices and assessment techniques (Duschl & Grandy, 2008).
Capps and Crawford’s (2013) study showed that teachers in the United States, a country in which ‘inquiry has been a buzz word in science education for many years’ (p.523), hold many misconceptions and myths about inquiry and equate it with questioning, student centred teaching approaches, and hands on teaching.

‘It was particularly troubling that many teachers in this study believed they were teaching science as inquiry even when they did not (ibid, p. 522).
The Community for science education in Europe

http://www.scientix.eu/web/guest/home

Science Education in Europe: Critical Reflection
(J. Osborne, J. Dillon, 2008)
Expansive learning
(Engeström 2000)

- Questioning/primary contradiction
- Historical analysis and/or actual empirical analysis
- Modelling the new solution
- Examining the new model
- Implementing the new model
- Reflection on the process and realignment with neighbours
- Consolidating the new practice
IBSL? IBST? IBSE?

What is Inquiry Based Science Education?

How shall we translate the concept into European context?

Is it all the same or are there differences in teaching inquiry in Science Biology - Chemistry - Physics Technology Engineering Mathematics
Where should Inquiry Based Science Education take place?
Hands-on?  Minds-on?
Minner, Levy, and Century (2010) argue that inquiry teaching has essential features which should be applied and which are described by the NRC (1996; and 2000, p.25) as following:

✓ Learners are engaged by scientifically oriented questions
✓ Learners design and conduct investigations
✓ Learners give priority to evidence, which allows them to develop and evaluate explanations that address scientifically oriented questions
✓ Learners formulate explanations from evidence to address scientifically oriented questions
✓ Learners evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding
✓ Learners communicate and justify their proposed explanation
[...] here was no statistically significant association between amount of inquiry saturation and increased student science conceptual learning.

However, subsequent model refinement indicated that the amount of active thinking, and emphasis on drawing conclusions from data, were in some instances significant predictors of the increased likelihood of student understanding of science content (Minner et al., 2010, p. 493)
These findings raise the question whether active thinking and decision making needs to be embedded in a full inquiry cycle or might be equally effective when applied outside the investigative context.
IBSE should be linked to:

IBSME: Inquiry Bases Science and Math Education
IBSMTE: Inquiry Based Science, Math and Technology Education
IBSMTAE: Inquiry Based Science, Math and Technology and Art Education

Hooks to motivate learners might be

Botanic Gardens, Science Centers, Museums etc.
Learning about the world of work
Mysteries incorporated
Nano-technology
Creativity – and arts etc.
Therefore, although IBSE has a long history in the United States, Capps and Crawford (2013) concluded that:

‘today there is still no consensus as to what it [IBSE] actually is and what it looks like in the classroom` (p.525)
There should be better alignment between pedagogy, curricula and assessment systems, ensuring that assessment reflects new teaching methods and that the curriculum facilitates inquiry rather than constraining it.

There should be better coordination between curricula, textbooks online resources and teacher competences
There is a need for more coherent and learning oriented professional development programs for teachers in order to improve their confidence and their repertoire of action in relation to Inquiry Based Learning.

IBSE has a great potential but is a challenging task.
‘Teaching isn’t an exact science. Uncertainty is in its nature. This uncertainty calls for wise, well-founded judgment. Uncertainty is the parent of professionalism and the enemy of standardization. It is what makes teaching interesting, variable, and challenging—a job that’s different every day’. (Hargreaves & Fullan, 2012 cited in Campell, 2013, p. 181)
From ‘open’ to ‘guided’ inquiry
Levels of Inquiry (Abrams et al., 2007) adapted from Schwab (1962) and Colburn (2000b)

<table>
<thead>
<tr>
<th>Level</th>
<th>Source of Question</th>
<th>Data Collection Method</th>
<th>Interpretation of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Verification</td>
<td>Given by teacher</td>
<td>Given by teacher</td>
</tr>
<tr>
<td>Level 1</td>
<td>Structured</td>
<td>Given by teacher</td>
<td>Open to student</td>
</tr>
<tr>
<td>Level 2</td>
<td>Guided</td>
<td>Given by teacher</td>
<td>Open to student</td>
</tr>
<tr>
<td>Level 3</td>
<td>Open</td>
<td>Open to student</td>
<td>Open to student</td>
</tr>
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Traditional teacher centred STEM Education

Teacher needs to know all the content specific knowledge

Knowledge is reproduced by students

Open Inquiry STEM Education

Teacher acts a companion and develops his knowledge alongside his students

Knowledge is totally produced/constructed by students

STEM Education adapted to students needs

Teacher needs to know all the content specific knowledge and knows when it is appropriate to offer it

Students individual knowledge development is scaffolded by teachers
Students ‘hands on engagement’ is a motivator but NOT an INDICATOR for learning.

Data analysis, interpretation and critical reflection is MOST IMPORTANT for learning STEM.
Scaffolding is the support needed to assist students in achieving their learning goals

- **Metacognitive**: Metacognition reduce the amount of mental processing
- **Procedural**: Methods to show a process
- **Strategic**: Reduce the problem to its core, finding other ways to approach the task
- **Conceptual**: Recognizing relationships between things

Once the idea is built the scaffolding can be removed
visual phenomenon
interpretation graphic
links to background knowledge
prompts and hints
explanation at the right time
articulate current understanding
Small group or partner work
teachers active engagement
Inquiry STEM Education is a gradually increasing challenge for learners

<table>
<thead>
<tr>
<th>Pre and Primary School</th>
<th>K 5-8</th>
<th>K 9-12</th>
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</thead>
<tbody>
<tr>
<td>• Simple questions</td>
<td>• Scientific question</td>
<td>• Questions lead to a research oriented investigation</td>
</tr>
<tr>
<td>• Observable phenomena</td>
<td>• Plan structured investigations collect, record and analyse data</td>
<td>• Plan and run research oriented investigation</td>
</tr>
<tr>
<td>• Ideas for possible solutions based on individual experience</td>
<td>• Explain, predict and use simple models based on data collected</td>
<td>• Use Math and Technology to conduct, interpret and present data and to improve the quality of your investigation, and your communication</td>
</tr>
<tr>
<td>• Plan a simple investigation</td>
<td>• Draw conclusions based on data collected. Discuss possible links; apply critical and logic thinking</td>
<td>• Draw conclusions while taking scientifically accepted knowledge into consideration</td>
</tr>
<tr>
<td>• Collect data</td>
<td>• Accept alternative ideas and predictions based on evidence</td>
<td>• Accept alternative ways to interpret data as long as these are well argued, sound and logic.</td>
</tr>
<tr>
<td>• Interpret data based in individual experience</td>
<td>• Present results while using tables and graphs</td>
<td>• Reflect critically on your own results</td>
</tr>
</tbody>
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**Discovery Learning**

Scientific Literacy

‘Drawing evidence based conclusions’ stands for a whole set of abilities that scientifically literate people are expected to have such as:

✓ being able to identify questions which can be answered by science.

✓ knowing how and whether this scientific knowledge can be applied

✓ being able to select and evaluate information and data, cautiously and consciously

(PISA 2006)
The teachers is a guide AND a sensitive master –

- someone who knows what his/her students are able to do themselves already and what kind of support they need to improve their knowledge and skills continuously.

- Someone who knows the characteristics of S-T--EM – related development (Nature of C-B-Ph-T-E-M) as well as

- the content specific learning goals (including the phenomenon) very well and

- is able to differentiate alternative from wrong/misleading approaches to solve problems.

- He/she listens to students ideas and is able to differentiate between creative approaches and those without any logic.
Lessons learned

Educational change in Europe should be implemented in line with a well–defined long-term vision, which incorporates the best features of national systems.

There should be more clarity about what constitutes impact for STEM projects and more systemic capacity to measure and monitor impact.

The duration of educational projects should reflect the long–term reality of school timeframes, in other words short–term interventions are not enough to ensure long-term change, even when ‘ multiplier ’ effects are taken into account.
THE 5E INSTRUCTIONAL MODEL

The BSCS 5E Instructional Model: Origins, Effectiveness, and Applications.


Biological Science Curriculum Study, July 2006
Engage

Exploration

Explanation

Elaboration

Evaluation

Encourages to **assess** their understanding and abilities – provide opportunities for the teacher to evaluate the process

**Challenge and extend conceptual understanding and skills** – develop deeper and broader understanding - apply this understanding

Focus attention on a particular aspect of engagement....demonstrate conceptual understanding - directly introduce a concept - learners explain their concept explanation from the teacher is added

.. assesses the learners **prior knowledge**... help to engage with a new concept ... and organise **students thinking** towards outcomes of current activities