Inquiry-based learning - what, why, how

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January 2021

Rationale

This document is part of an article on research which was carried out on how to capture Inquiry-based learning (IBL) in classroom-based videos (Baartman, Vos & Rosenvinge, 2021). This document serves to provide student teachers with information on IBL and ample references to read and investigate further. In line with our choice for IBL as a pedagogical approach we recommend that student teachers first gain experience with IBL through observations of the videos and through IBL seminars where the lecturer uses the inductive approach.

Introduction

Both in education and in society-at-large, there is a need for complex problem-solving skills, inquiry-skills, creativity, and critical thinking skills (Ludvigsen et. al.,2014; P21, 2019; Vincent-Lancrin et al., 2019). This need is also reflected in the curriculum reform in Norway for 2020 (UDIR, 2020), which aims at *deep learning* with a focus on reflection on learning, exploratory learning, complexity, and inquiry skills. Nine years after introducing the previous curriculum promoting IBL in science, experienced science teachers in secondary school only implemented fragments of IBL, although they observed increased interest, motivation, and curiosity when they did (Haugan, Gutvik Korssjøen & Skarpnes, 2017).

During our work in teacher education at a Norwegian university, we observed that both lecturers and student teachers need an operationalization of what concepts such as *exploratory learning* and *inquiry skills* entail. The new curriculum describes that pupils should develop an inquisitive mindset (Norwegian: *utforskertrang*) and be able to ask questions and explore (UDIR, 2020). Yet, how does a teacher achieve this? Most students neither experienced exploratory learning or inquiry skills during their school time, nor do they see it when they go on teaching practice or in lectures at the university.

We will approach the curriculum reform from the perspective of Inquiry-based learning (IBL) for three reasons. First, IBL covers the two areas: inquiry skills, and exploratory learning. Learning about IBL will thereby support the curriculum reform. Secondly, IBL is internationally well-documented and researched, which we will summarize in the next paragraph. Lastly, we gained experience with IBL (Baartman, 2015; Gjesteland & Vos, 2018), and learned that to implement IBL in classrooms one needs to see, feel, and experience it.

Inquiry-based learning

IBL has its roots in science education and dwells on John Dewey's progressivisms with a focus on learning-by-doing, experiencing real phenomena, and exploring through hands-on activities (Dewey, 1928), on constructivism, and on the constructivist learning theory (Papert, 1993). IBL is often associated with, and to a certain extent rooted in, science education. However, IBL can be considered wider, because it is an instructional approach that can be applied in any subject area (Harlen & Qualter, 2018). The IBL activities we designed lie on the crossroads of science, technology, engineering (design), and mathematics (STEM). This does not mean that IBL cannot be used in languages, arts and other subjects, on the contrary. We will first look at definitions of inquiry and

thereafter at characteristics of the IBL activities, the teacher role, and the phases of a typical IBL lesson in terms organization and planning.

IBL definitions and characteristics

Inquiry skills are skills to tackle a problem by exploring, using inquisitive questions, planning, and carrying out an experiment, or to critically investigate a phenomenon. An important aspect is the skill to think out inquiry questions throughout the whole process. Traditionally, inquiry questions were associated with requests for explanation or justification (Stein, Engle, Smith, & Hughes, 2008) by the teacher in a discussion of answers to a task. By contrast, in IBL the aim is that *pupils* develop an inquisitive mind through expressing their own questions. Ideally, an inquiry starts from pupils' question, and a teacher can trigger these questions. Genuine inquiry tasks essentially aim at provoking pupils' thinking, challenging them to consider different strategies and to build new knowledge.

Thus, in IBL, inquiry questions are the start of pupils' activities. To design for inquiry, Resnick and Rosenbaum (2013) define the term *tinkerability* as an open process of exploring, experimenting, and trying new things. An important design principle for their activities is to start from the physical processes that allow for immediate feedback through the visible results. They promote the design of physical activities that are easy to get started with and easy connect to, tasks that are specific, tangible, and involve the use of several senses.

Harlen and Qualter (2018) state that inquiry skills are used to develop understanding; inquiry skills are a set of skills used in the process of discovery and gaining knowledge, such as observe, identify, search for information, interpret, plan, explore, investigate, predict, experiment, analyze, test, seek evidence, reflect. They mention IBL characteristics such as: (1) an inductive approach (pupils experience and investigate before being exposed to theory), (2) dealing with relevant, interesting, and meaningful problems, related to the world outside school, (3) active investigation of real objects, materials, and events, (4) promoting talk, dialogue, communication and collaboration in various forms.

A central tenet in IBL is the promotion of thinking and communication among pupils. Both Harlen and Qualter (2018) and Boaler (2016) address this. To encourage thinking, Boaler (2016) designs mathematics tasks, which often have visual or tangible components. Another characteristic is that she advocates tasks to be *low-floor, high-ceiling and wide walls* tasks. Such tasks are (1) easy to understand and to get started, often because of visualization of the problem or the use of manipulatives, (2) challenging for different pupils and different cognitive levels, as they start often hands-on and open up for deeper investigation and exploration, and (3) cater for different strategies, approaches, and solutions. IBL tasks are typically low-floor, high-ceiling, wide-walls task. The tasks start often with a problem that is easy to grasp, because it is concrete and related to the world.

Savery (2006) describes IBL as an instructional and curricular learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem.

Based on the researchers (Boaler, 2016; Harlen & Qualter, 2018; Petrich et al, 2013; Resnick & Rosenbaum, 2013; Savery,2006) mentioned above, we summarize what can be considered IBL characteristics:

1. Inductive approach - pupils experience and investigate before being exposed to theory, subject content, and definitions etc.
2. Pupils must have the responsibility for their own learning. Pupil agency/pupil ownership of learning is key and thereby their contribution to solutions;

3. Pupils should be using and developing inquiry skills;

4. Activities or tasks should:
    a. be engaging, interesting and relevant to children, motivating questioning and problem solving;
    b. deal with problems that are relevant, interesting, meaningful to children, and related to the world outside school;
    c. involve problem simulations that are be ill-structured and allow for free inquiry; When a problem is well-structured learners are less motivated and less interested in the development of the solution;
    d. involve learning with issues that are valued in the real world;
    e. involving active investigation of real objects, materials and events or phenomena;
    f. promote talk, dialogue, communication, and collaboration in various forms. Collaboration is essential. In the world after school most learners will find themselves in jobs where they need to share information and work productively with others;
    g. (if possible) involve creativity and the use of multiple senses: tactile, visual, kinesthetic etc.;

5. Learning should be inter-disciplinary;

6. What pupils learn during their self-directed learning must be applied back to the problem with reanalysis and resolution. A closing analysis of what has been learned from work with the problem and a discussion of what concepts and principles have been learned are essential;

7. Tasks should be 'low-floor, high-ceiling and wide walls' easy to start with.

8. Assessment of pupils's performances should focus on their progress towards the goals of IBL.

Note that one cannot claim that a lesson or activity is IBL when it bears just a few characteristics. It is the combination of characteristics and the different role of both teacher and pupils that makes IBL a different pedagogical approach. If you consider the characteristics you will be able to conclude that we are not talking about tasks or problems that will be solved within a few minutes. On the contrary, the inquiry process can stretch over several hours, days, or even weeks. So far the characteristics of IBL learning activities, we will now head to the role of the teacher.

Teacher's role during IBL lesson

The role of the teachers in IBL pedagogy is crucial. First, the teacher's role in the preparation is that of a creator or designer of learning activities. The design process is based on the design cycle: Plan-design – test – redesign (vd Akker, 2006). This implies that a thorough design and planning of the activity has taken place. The teacher has carefully designed the activity and decided on grouping, time available, space and place. In the design and development of appropriate learning activities for the target group the teacher needs to have good knowledge of the content, knowledge about what the pupils know from before, what they have experienced, learned, and what engages and interests them. The tasks should challenge the pupils, and encourage, or even demand them to actively collaborate. The designed activities should be relevant, meaningful, most likely specific, tangible, involve the use of several senses, and the body as a whole(kinesthetic).

Secondly, we are looking at the teacher's role in class. The introduction of an IBL activity is usually short and provides a clear problem or task/goal. During the lesson, the teacher should guide the pupils in a way that encourages thinking and inquiry skills. The teacher should avoid telling the children what to do and avoid too much scaffolding and too much control. When a problem is well-structured learners are less motivated and less interested in the development of the solution (Savery, 2006), and pupil ownership decreases. The teacher should encourage the pupils to think aloud, allow time for thinking, give room to their own ideas, solutions, strategies, and questions. Ideally the tasks can be approached and solved in different ways and there are more correct solutions or answers (Harlen, 2018). Formative assessment is a continuous process during IBL learning experiences. Feedback and feed-forward are provided by the tasks itself through observations of the results while working with materials, technology etc., by peers, and by the teacher. The feedback from the teacher is most prominent in the closing of the activity, where findings, results, and solutions, as well as strategies and techniques, will be discussed and shared.

Probably the most crucial part of the pedagogical approach of IBL and the most difficult to adopt for teachers, is the inductive approach, grounded in the constructivist learning theory. This is explained by Ponte (2005) as follows; in inquiry-based teaching, the emphasis is moved from the *teaching* activity to the more complex activity of *teaching and learning* (Ponte, 2005). The teacher's role is no longer merely to transmit information or knowledge to attentive and silent pupils. In an inquiry-based classroom, it is the teacher's responsibility to propose learning situations that will help pupils to build their own knowledge. This is achieved not only by developing different actions aimed at promoting pupils' learning, but by placing the center of activities in the hands of the pupils as a collective. In IBL the teacher is more a guide and a coach than an instructor. The teacher does not give ready answers. The teacher facilitates learning and should strengthen understanding by helping learners to clarify their intentions trough reflective conversation (Petrich et al., 2013). It is in this conversation that pupils are encouraged to think aloud and put words to their thoughts. The teacher encourages, activates, is monitoring, questioning, challenging, supplying feed-forward to uphold and build confidence. The teacher should combine diving in with stepping back (Resnick & Rosenbaum, 2013). In IBL, the teacher is expected to engage the pupils in rich activities based on challenging tasks, working autonomously (usually in small groups) and collectively, emphasizing discussion and negotiation of meanings (Bishop & Goffree, 1986; Ponte, 2005).
In practice this results in a paradigm shift on the part of the teacher. The teacher does not start with explaining facts, showing procedures, disseminating knowledge, and providing subject content. The teacher starts posing a problem to be solved, setting a challenge, an inquiry. This is contrary to the deductive approach that most teachers practice, and therefore difficult to change. Without this inductive approach, IBL is watered down to something that maybe looks like IBL but is not. In IBL teachers should radically move a way from the teacher centered instruction. IBL starts with pupil activity, pupils that experience and explore. When the ratio *teacher activity/pupil activity* in a traditional lesson is close to 80:20. In an IBL lesson this will be the other way around, close to 20:80.

Phases in IBL lessons

There are different views on the different phases of a typical IBL lesson. Stein et al. (2008) propose a three-phase model: the launch phase, the explore phase, and the discuss and summarize phase. Canavarro, Oliveiro and Menezes (2012) advocate four phases, emphasizing the systematization of (mathematical) learning as a fourth phase of particular importance. Pedaste (2015) carried out a literature review on 60 articles on IBL, deducting a model with four main phases and some sub-phases, with two alternatives in the central phases (See Figure 1). These alternatives exist due to different activities when working with data, or with actual physical experiments.

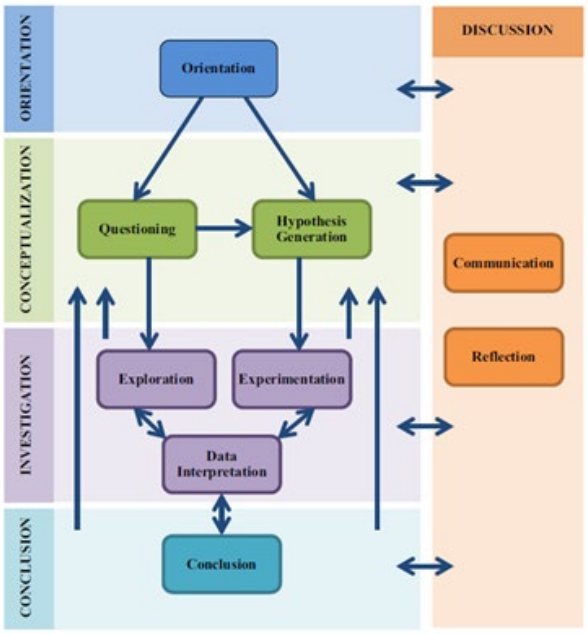

Figure 1: Inquiry-based learning framework (general phases, sub-phases, and their relationships). Pedaste et al. (2015).

One does not need to start with pure IBL and full pupil agency. Ellermeijer (2012) distinguishes five different levels of inquiry, that can be of help to learn to implement IBL in teaching and learning. The five levels of inquiry (Ellermeijer, 2012) are:

1. **Interactive demonstration**, the teacher demonstrates and probes for inquiry with the pupils. The teacher guides the inquiry process. An example could be the use of Concept Cartoons (Naylor &Keogh, 2000) in class;
2. **Guided discovery**, the pupils carry out an experiment guided by the teacher. The pupils receive instruction on what and how to carry out an experiment. Pupils observe and measure;
3. **Guided inquiry**, the pupils are guided in their investigation and inquiry by the teacher for example though a worksheet with (open) questions;
4. **Bounded inquiry**, the goal is set by the teacher, but the pupils decide how and what to investigate and experiment. Pupils should come up with their own questions within the task set;
5. **Open inquiry**, pupils come up with their own genuine questions and get the opportunity to find answers with others. Examples: 'Why does an eclipse of the moon occur more often than an eclipse of the sun?', 'How can (certain) insects walk on water?' 'How do you know how far away a star is?' 'How/why ….?

Concluding remarks

We hope that this document will supplement the observation of a series of videos on IBL in classrooms that have been produced at University of Agder, and lead to a better understanding of IBL. Our ultimate aim is that student teachers and teachers get interested in IBL and learn to put it into practice. This is challenging and teachers may feel uncomfortable with this new and different pedagogical approach, but we hope that teachers will experience that the downside is far outweighed by the positive experiences of the pupils and the learning outcomes in the long run. When IBL is being implemented some key concepts of the new curriculum (LK20) will be covered.

More important though is that the ideas behind the new curriculum will be met: pupils that are better prepared for the unknown future, because they have learned to tackle new problems, to think creatively, to communicate and collaborate, and they have gained resilience.

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