

Inquiry-based and learner-centered chemistry education

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This article discusses inquiry-based science education (IBSE), which is important for example in education for sustainable development. Especially learner-centered point of view is considered to be essential. The article presents benefits and possibilities in using inquiry-based learning in teaching, such as using students' questions in a learner-centered education. Additionally, challenges and possible solutions are addressed, particularly those connected to context-based inquiry. Finally, aspects on assessment and the important role of the teacher in inquiry-based learning, are discussed.

Student's own activity and curiosity is generally considered to be important in learning chemistry. For example in inquiry-based learning "the idea is that individual's developing knowledge of a subject is driven by curiosity rather than passively absorbing information" (Horizon 2020, IBSE, 2012). Student should therefore be in the center of education. There is no single definition for student-centered (or learner-centered) education, but for example in the study by Lea, Stephenson and Troy (2003) higher education students viewed learner-centered education as an approach where for example students are "more responsible for and in control of their own learning". Inquiry-based learning and teaching can also be defined in several ways. It can be a way to study, learn, work or think (Abrams, Southerland, & Evans, 2008; Aksela, 2005). Inquiry-based learning is "finding things out" (Morrison, 2015). In science education, the term "inquiry-based science education (=IBSE)" is often used. Variation of IBSE are according to Crawford (2014) are for example project-based, authentic science, citizen science, and model-based inquiry.

An inquiry-based learning process can begin from the students' own questions, from which the students design and carry out an inquiry. That kind of an inquiry is in many cases referred to as open inquiry. The research question can also be given by the teacher, and the students can carry out an inquiry planned by the teacher (confirmatory and structured inquiry, look more on chapter "SOLO taxonomy helping practical chemistry instruction"). The research question might also be given to the students, but students receive more freedom in planning their own inquiry. This can be called guided inquiry. (Schwab, 1962; Abrams, Southerland, & Evans, 2008) Even if the ways to define and carry out inquiry-based learning vary, Abrams et al. (2008) have defined inquiry as: "Any cognitively appropriate activity that echoes some subset of the practice of authentic science in which students are expected to engage with resources (literature, people, environment) around the generation or answering questions or the solving of problems."

When choosing an IBSE-method, the goals have to be taken into account. Is the goal to learn content, scientific practices or something about inquiry or chemistry as a science, for example? Also resources available, teachers' knowledge, students' inquiry skills and the content to be

learned affect the “optimal form of inquiry” (Abrams et al., 2008). It is important to take into consideration, what the goal is and which level of inquiry fits for that goal.

Benefits of IBSE

Inquiry-based learning and teaching has lots of benefits, and it is central in the unit of chemistry teacher education both in terms of research and teacher education (Herranen, Tuomisto, & Aksela, 2015). For example courses inquiry-based teaching *I* and *II* concentrate on IBSE. In the courses, it has also been examined how students understand inquiry and apply it into their projects (Fooladi, Herranen, Kousa, & Aksela, 2015). IBSE has shown to be motivating for the students (Rocard et al., 2007). It can also support students’ inquiry skills (Aksela, 2005) and thinking skills (Kipnis & Hofstein, 2008). Practicing inquiry is a natural way to work and learn in science. It is part of the nature of science (Chinn & Malhotra, 2002). Especially guided-IBSE has potential to increase science achievement (Jiang & McComas, 2015).

In order to support the students to be able to participate in discussion and decision making for sustainable future, education for sustainable development (ESD) is crucial. In ESD, inquiry-based education is considered important (Juntunen, 2015). Juntunen (2015) has suggested that students could choose the focus of inquiry and it could relate for example to raw materials or consumer products. In ESD socio-scientific issues are important to be included, because it for example improves the appreciation of science in society and in students’ own lives as seen in the review by Juntunen (2014). Discussion and argumentation is important both in ESD and in inquiry-based learning (Juntunen, 2015). Research findings in science have to be communicated to the society to enable socio-scientific discussion. Thus education that takes into consideration the social nature of science, has a possibility to be relevant for the students (Sadler, 2009) and therefore is student-centered. A student-centered approach has been suggested to be used in education for sustainable development in chemistry (Burmeister, Rauch & Eilks, 2012; Tolppanen, 2015).

Use of contexts in IBSE

Contexts, such as food, are often considered important in IBSE. This can be referred to as context-based education. Contextualization is one possible way to make science education relevant to the students (Gilbert, Bulte, & Pilot, 2011). Context-based learning can connect inquiry to students’ everyday life or to something that is societally meaningful. Students may however have difficulties in transferring knowledge from one situation to another (Gilbert, Bulte, & Pilot, 2011). Gilbert et al. (2011) have therefore suggested that the students should be given possibilities to form and modify their mental maps. Mind mapping tools using ICT can be applied to this. Mind mapping is also one possible tool in formative assessment.

In order to transfer information from one situation to another, a student has to identify analogies between the present and previous situation. When planning teaching, contexts which

have enough analogies should be chosen, if there is also a goal to promote learning of concepts. In addition to that, students should be given possibilities to practice talking chemistry in different situations. Students could also benefit from building information by themselves and with other students. Furthermore, sufficient content knowledge helps in transfer between contexts (Gilbert et al., 2011)

Purpose of questions in IBSE

Asking questions and searching for answers are a part of the nature of science. Researchers as well as students ask questions of the issues that they are interested in. In IBSE, a question that leads to investigation is important (Crawford, 2014). Students' own questions can be used to support inquiry and as a starting point in IBSE. The potential in students' questions to teaching and learning science has been discussed for example by Chin & Osborne (2008). Students' questions are of importance when designing research questions, but also in other stages of inquiry (Chin & Osborne, 2010). It has been suggested that using students' own questions can support student-led science teaching and learning (Herranen & Aksela, 2016)

Students ask spontaneous questions in class, but formulating questions is also something you can practice together. Question stem -technique is one possibility to diversify students' questions. Question stems are sentences given to the students, which they have to complete. Question stems can be chosen to for example support conceptual understanding or causal connections, such as: "explain why...? question stem (King, 1990).

Assessment in IBSE, and the role of the teacher

IBSE should address the question of assessment. The goals of inquiry have an effect on how the students' learning can be assessed. The teacher has to clearly set the goals in IBSE. The challenge is to target assessment to the goals that have been set. The goals have to be articulated to the students, and also they have to be guided to set goals themselves.

It has been suggested that students' questions could be used as a part of assessment (Pedrosa de Jesus & Moreira, 2009). Students' questions can be gathered for example during inquiry. Questions can be used especially in formative assessment. Formative assessment is interactive and continuous, and both the students and the teacher participate in it during teaching and learning (Black, 2003). Questions can therefore be used as self-assessment (Chin & Osborne, 2008).

In assessment and during the whole learning process, the teacher has an important role in supporting the students. In Crawford's (2000) case-study, it was studied that the teacher takes up the roles of a diagnostician, a guide, an innovator, a motivator, an experimenter, a researcher, a modeler, a mentor, a collaborator and a learner. The teaching context in the school

can have an effect on how the teacher's implements inquiry-based activities (Hong & Vargas, 2016). In addition to that, Eick and Reed's (2002) study results suggest that teachers' personal learning histories may have an effect on their role identity as inquiry-oriented science teachers. They proposed that teacher education should strengthen student teachers' inquiry identity. Also students need time to learn inquiry-based learning.

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