Holistic and inquiry-based teaching of sustainable chemistry

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The most important function of the branch of chemistry and teaching is to promote sustainable development. This article discusses central viewpoints of the teaching of sustainable chemistry. This article is based on a doctoral dissertation, where such information is the starting point: we will encounter great challenges connected to the viability of the earth, to our health and peace in the near future at the latest. Our students are the future citizens in preventing and solving these challenges. Chemistry teaching may strengthen the necessary civics, because chemistry as a branch of science is in a great role in the development of the world. In addition to environmental conscious teachers, chemists committed to sustainable development are needed. Sustainable development and augmentation towards ethical responsibility is emphasized widely – in the Finnish National Core Curriculum for Basic Education, in national and international teaching strategies, in the research literature of chemistry teaching and in the chemical industry. The problem is the fact that handling of topics of sustainable development completely and experimentally is still quite concise in the teaching of chemistry. In this article, examples for studying a topic in chemistry teaching are introduced.

In the branch of chemistry, sustainable development concerns especially the lifespan of products and green chemistry (Anastas & Kirchhoff, 2002; Nair, 1998). In green chemistry, the molecules affecting the lifespan of products are such that they only use up a bit of energy and resources, they are non-poisonous to use, they can be recycled and in the end they decompose safely in the nature. This applies to every product, substance and material around us. Lifespan-based thinking and green chemistry are a central factor in the cherishing of the viability of the world and in the ecological stability (Rockström et al., 2009).

In chemistry teaching, sustainable development is interdisciplinary and a topic that is based on society. The teaching is connected to the actual workers in society and to problems (Burmeister et al., 2012). When the knowledge of chemistry is a part of the cause of the problems, solutions and scopes for action, a student experiences chemistry as significant (Juntunen & Aksela, 2013a, Burmeister, Rauch & Eilks, 2012). At the same time, the student's ability to act in the individual and community levels increases in building a more sustainable future (Paloniemi & Koskinen, 2005).

Students find personal, concrete topics interesting (Juntunen & Aksela, 2013a). Students can decide for themselves the subjects of different research assignments e.g. concerning raw materials, consumer goods, foodstuff and water. This is how chemistry teaching can be based on themes of sustainable development – for example on the lifespan of different products, on clean water, on the particulates of air and climate change, on chemicalization of the environment, on fertile soil and recycling of fertilizers, or on circular economy or on the chemistry of healthy food.

How to teach sustainable development?

As a result of the dissertation's (Juntunen, 2015) design-based research, new information, on how to teach sustainable development, was acquired. Its learning occurs in social interaction, for example through argumentation or self-reflection. Students can themselves choose the research subjects and approaches. Teaching is socio-constructive and contextual in theoretical terms (Tani, 2008; Tilbury & Cooke, 2005). Figure 1 illustrates the practical dimensions. Teaching methods that completely support sustainable development are cross-curricular, they open up in society, social, student-centered, favor exercises on argumentation and on practical work. The topics are based on society. Then diversified topics are considered through critical and solving-centric glasses. Often topics touch on green chemistry and complex causal relations (Juntunen & Aksela, 2014b). One practical example of this kind of teaching is the researching of the lifespan of a product from the students' starting points.

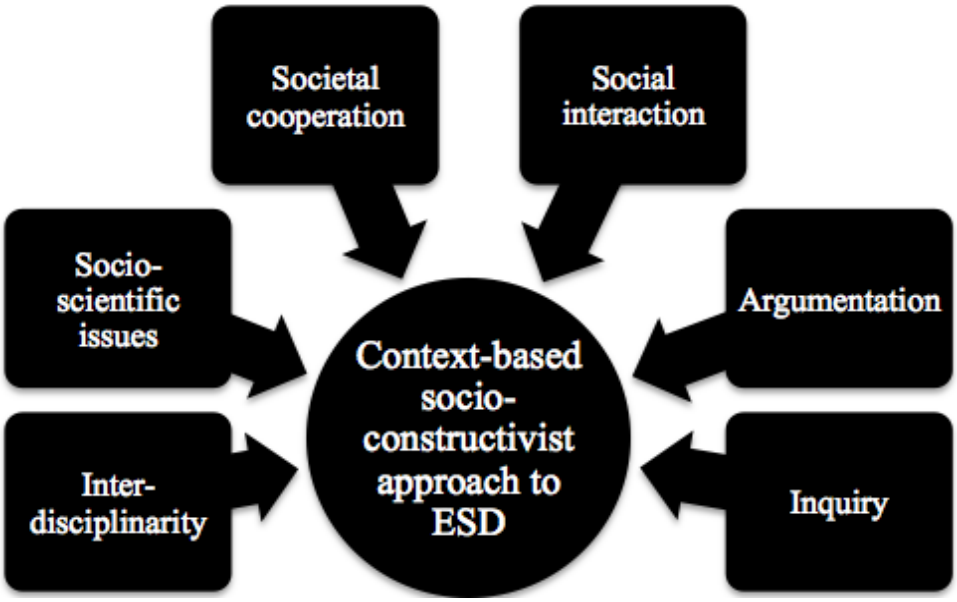

Figure 1. The elements of a contextual and socio-constructive teaching of sustainable development in chemistry (Juntunen & Aksela, 2014b).

As a result of the dissertation, new, lifespan-themed, inquiry-based teaching models of chemistry were acquired and from these a communally developed synthesis of teaching models (Juntunen & Aksela, 2013b). Here a product's lifespan is researched during a period of a few weeks, where the student has chosen the product based on their own interests. A multidisciplinary approach improved the students' understanding of the usefulness of chemistry. The students experienced inquiry-based, social, open and student-centered studying as positive. The research project also increased the students' natural science and ecological argumentation skills in social and in environmental conscious pondering (Juntunen & Aksela, 2013a, 2014b). The lifespan of a product -teaching method and other practical tips of teaching and assignments can be found from a manual "Sustainable Development in Chemistry Teaching" (Juntunen, 2016), which is based on the doctoral dissertation (Juntunen, 2015).

More solutions of sustainable development to chemistry teaching

For the time being, cross-curricular, solution-centric learning of chemistry has been quite a small part in the teaching of chemistry (Burmeister, Rauch. & Eilks, 2013; Kärnä, Hakonen, & Kuusela, 2012; Tirri, Tolppanen, Aksela, & Kuusisto, 2012). Teachers experience that there are many challenges when teaching about sustainable development. These include e.g. the complexity of topics and interdisciplinariness, the lack of suitable teaching materials, controlling the group of students, the lack of time and the amount of time used to prepare for classes. The practicing of skills necessary for new teaching methods, the ability to connect knowledge of chemistry into larger entities and ethics, and the general lack of interest in studying are challenging from the point of view of students. Help can be offered to these challenges in further education and in the work communities inside schools. Everything cannot be possibly improved at once, instead small steps at a time should be taken, while learning together. Students reach a specific level in their research, which they are able to reach. It is enough and it is a good starting point (Juntunen, 2015).

When we want to support students' versatile studying skills and civics, it is most important to instruct the students to generally connect knowledge of chemistry to sustainable development. When dealing with global and local challenges, we should focus besides to the causes of the challenges also in solving these challenges. Pondering on different scopes for action is a part of the contents of teaching and it promotes the student's ability to act or the competence to affect. Just a mere introduction of problems, without concrete pondering on solution – or alternative course of action, may lead to crippling prospects.

In the assignments, decision making, ethical reasoning and articulation of opinion concerning interest conflicts of environmental questions may be practiced (Oulton, Dillon, & Grace, 2004; Wilmes & Howart, 2009). Suitable approaches here could be e.g. debates and acting as an opponent to other students' works, where it is possible to learn to "speak chemistry". Learning, as a new dimension, occurs more in social interaction between equals and workers of society.

Education of sustainable development unites global -and future education. It is important for teachers to remember that the challenges of mankind may be quite abstract from the students' points of view. A part of the challenges are invisible to us in our daily lives. On the students' level of thinking, understanding requires a development of complex skills in system thinking, but it is possible to children in some extent (Tilbury & Cooke, 2005; Wylie, Sheehy, McGuinness, & Orhard, 1998).

As a summary, we can state that education on sustainable development is needed more in chemistry in all levels of education. A suitable approach can be found to people of all ages. When students are encouraged both to study and to influence, chemistry is connected to actual, social themes and activities – experimentally and completely, and it encourages towards learning about chemistry.

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