

Education for Sustainable Development in Chemistry Teacher Education

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This article looks at education of sustainable development and research in The Unit of Chemistry Teacher Education in the University of Helsinki. This article presents the unit's strategy for sustainable development and examples on how it is carried out in education. In addition it is described, how with the help of design research, we are able to promote practical teaching of sustainable development. Finally, the skills that are central in promoting sustainable development are presented and as well how to support these skills in meaningful teaching of chemistry and in its evaluation.

"If we want a greener planet, and sustainable futures for all, we must ask more from our education systems than just a transfer of knowledge. We need our schools, universities and lifelong learning programmes to focus on economic, environmental and social perspectives that help nurture empowered, critical, mindful and competent citizens." (Aaron Benavot, Director of the GEM Report, UNESCO, 2016)

Sustainable chemistry is one of the areas of focus in research and education in the Department of Chemistry in the University of Helsinki, as well as in our teacher education. Chemistry and its know-how have a central role in promoting sustainable development and in solving global challenges through basic research, education and innovations.

There is a great need for the promotion of education for sustainable development (ESD) worldwide (Unesco, 2016). Teacher education has a remarkable role in promoting a sustainable future. Teachers have a long-term influence: Every teacher influences at least for a hundred years: first during the time that they work and later through the students they have instructed. In order for the education concerning sustainable development to be systematic and for the teachers to get the basic seeds (knowledge, skills and pedagogical know-how) necessary for its teaching, we came up with a strategy (see later in this article) for teaching sustainable development with our research group. According to previous researches, (Burmeister & Eilks, 2013; Juntunen & Aksela, 2014) teachers and their instructors often have insufficient knowledge and skills in sustainable development and in promotion of its chemistry educationally. There is an insufficiency of teaching materials in chemistry within the different dimensions of sustainable development.

The new Finnish National Core Curriculum also obliges us to promote the teaching and developing of sustainable development and as well to train teachers for it. A sustainable future is a central part of both the aims for wide knowledge as well as the aims of chemistry and contents in the new National Core Curriculum for Basic Education in 2014 (The Finnish

National Board of Education, 2014) and National Core Curriculum for General Upper Secondary Education 2015 (The Finnish National Board of Education, 2015). In chemistry teaching, education for sustainable development (ESD) should be emphasized also from the point of view of ethical and moral questions, and the themes should be looked at in local, national and international levels.

Our aim is to educate the future generation as responsible future citizens. We are committed in our education through our course “Sustainable Development in Teaching” to a national society’s commitment “The Finland we want by 2050” (Ministry of the Environment, 2016). Current circular economy is one of the themes in our education: concerning the topic, we cooperate with the industry, companies and research units. Our education is built so that sustainable development in teaching is promoted (figure 1) by emphasizing especially: inquiry-based lifelong learning; student-centered education; learning community and cooperation in the LUMA community and exploiting modern technology in education, learning, sharing of information and in conversation (e.g. Tuomisto & Aksela, 2015; Aksela et al, 2016). We especially think of the learning community as a central element in promoting the teaching of development. It is possible for everyone to learn from each other in a good interaction.

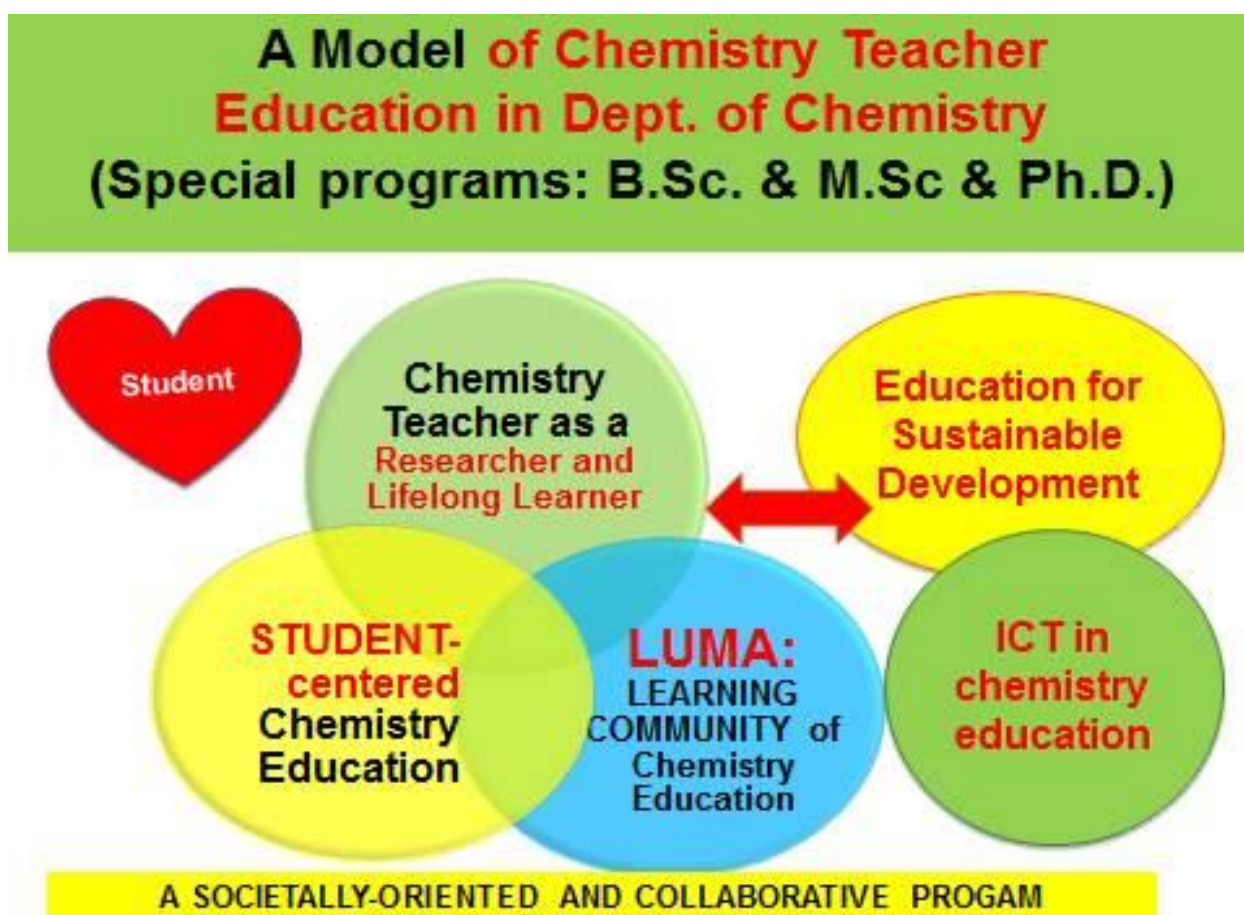


Figure 1. The central principles of sustainable development in teacher education in chemistry: (i) a researching teacher and lifelong learning, (ii) student-centered education (our motto: “Student inside the heart”) and (iii) a strong interaction in a learning LUMA community. Modern technology is exploited in a versatile way in connections suitable for chemistry education.

The strategy of sustainable development in teacher education

Sustainable development is a world-wide, regionally and locally happening continuous and organized societal change, where the aim is to secure good opportunities for living for the current and future generations (Ministry of the Environment, 2016). It contains the following four dimensions: ecological, economic, social and cultural.

In our training, the education for sustainable development consists of the following central parts: 1) chemistry and its teaching in a context (e.g. climate change), 2) the four dimensions of sustainable development, 3) Pedagogical Content Knowledge (PCK) and 4) exploiting modern technology in teaching. Sustainable chemistry and its possibilities are emphasized especially in the mandatory courses “Green Chemistry” and “Mathematics and Natural Sciences in Society”, where cooperation occurs with the industry, companies and with research units. In all the shared courses of chemistry education (e.g. Inquiry-based Education I and II as well as Models of Chemistry and Visualization), the above mentioned four parts are aimed at taken into consideration.

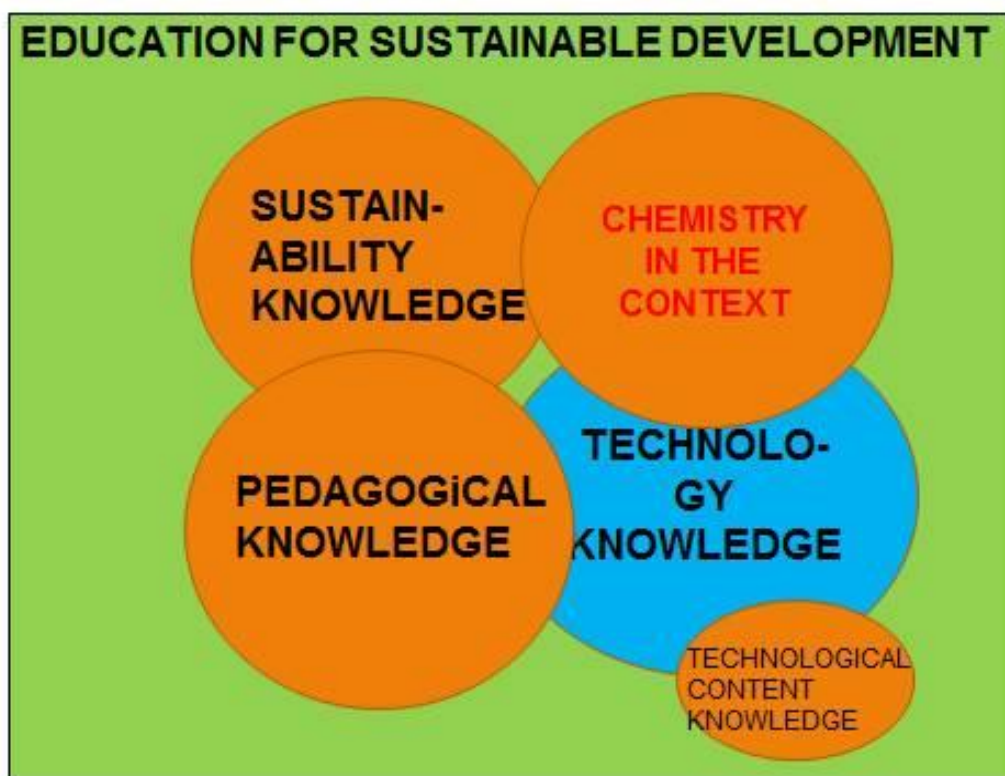


Figure 2. The areas of education for sustainable development in our unit’s education. For example a strong knowledge of TPCK (Technological Pedagogical Content Knowledge) is needed in microcomputer-based laboratory (MBL) teaching.

We take sustainable development into consideration in the contents and realizations of our courses aimed for teachers, but also in teachers’ further education and in our other operations. This strategy includes the following four parts: 1) Multidimensional education on sustainable development, 2) Interdisciplinary education on sustainable development, 3) Emphasizing the principles of green chemistry and 4) Responsible purchasing and sustainable consumption.

Sakari Tolppanen and Marianne Juntunen's doctoral dissertations connected to education on sustainable development and other researches of the unit have been exploited in coming up with this strategy.

We look at global themes such as climate, water and food multidimensionally in our education. Our aim is to use as few substances as possible and to minimize waste, to use safe chemicals and approaches as well as to exploit modern technology and equipment in microchemistry. In our teaching, we use versatile approaches that activate students for example inquiry-based studying, argumentation and drama as well as versatile formal and summative evaluation.

We develop education on sustainable development through research. During the last couple of years, the following two courses on sustainable development have especially been the subjects of research: 1) *Sustainable Development in Teaching*, where the topic is carried out student-centered and in an interdisciplinary way, and 2) *Mathematics and Natural Sciences in Society*, where circular economy is a topic. It has been carried out in cooperation with the Chemical Industry Federation, companies that specialize in circular economy, schools and with teacher trainees. This course is also a part of LUMA FINLAND development program that is funded by the Ministry of Education and Culture. In the implementation of the course *Sustainable Development in Teaching*, we have taken part in a Nordic ActSHEN cooperative project (Action for Sustainability in Higher Education in the Nordic region). Its aim is to develop approaches e.g. student-centered approaches in learning about sustainable development in a way that activates higher education students.



Figure 3. Active and communal learning, student-centered, in our innovative course *Sustainable Development in Teaching*.

Design-based research as a promoter of education for sustainable development

Communal design-based research (Pernaa, 2013; Pernaa & Aksela, 2013) has been observed as a good tool for widening the gap between theory and practice and therefore to promote education for sustainable development based on research. This has been exploited in our unit since 2002. Design-based research is a central research method in almost all of our theses (Aksela & Pernaa, 2013). It has been used for example in developing new practical work for the ChemistryLab Gadolin in cooperation with companies and students training to be teachers (Aksela & Ikävalko, 2016). In figure 4, the outputs and different stages of design-based research that we use are described.

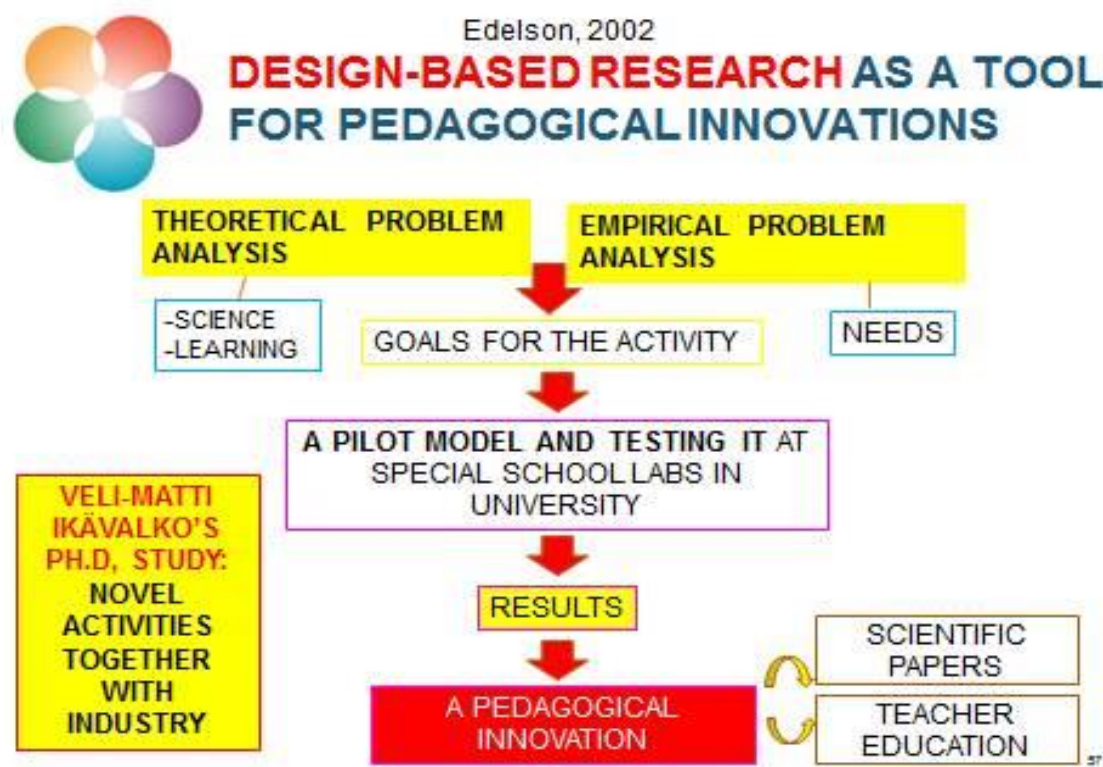


Figure 4. The stages of a multicycled design-based research. The research starts with the mapping of needs (empirical problem analysis) and of previous research information (theoretical problem analysis).

New innovations have been tested in the ChemistryLab Gadolin with students and teachers. The promotion of sustainable development is one of our main themes in the ChemistryLab Gadolin that operates as our unit's development and research centre. Our partners as well as teachers-to-be, go into the matter through different pedagogical innovations that have been developed communally (e.g. Aksela & Boström, 2012) and through works that have been developed in cooperation with companies (Aksela & Ikävalko, 2016). There are around ten companies that cooperate with us.

Design researches that are connected to sustainable development and chemistry are presented in more detail in the following articles of this anniversary book. For example in the doctoral

dissertation of Marianne Juntunen, new approaches for education on sustainable development have been developed with teachers in teaching about a product's lifespan and in developing skills of argumentation. On the basis of this dissertation, a practical guide for teachers, funded by the Ministry of the Environment, has been created, which is exploited both in teachers' basic and further education. In Veli-Matti Vesterinen's doctoral dissertation, the promotion of sustainable development has been considered from the viewpoint of the nature of chemistry as a science. In Jaana Herranen's ongoing doctoral dissertation, education of sustainable development has been promoted through inquiry-based learning and making questions and as well new pedagogical ways to promote student-centered learning of chemistry have been created. In Jukka Rautiainen's doctoral dissertation, education on sustainable development has been developed in chemistry education in universities through problem-based learning. Then in Johannes Pernaa's doctoral dissertation, new digital approaches have been developed communally with teachers in developing chemistry education and in increasing the understanding of chemistry. Since 2002, we have acquainted us especially with the realization of practical work and molecular modelling by using new approaches and by producing materials through design-based research.

Our aim is to exploit research on education of sustainable development in the realization and planning of the LUMA operations. For example on the basis of Sakari Tolppanen and Marianne Juntunen's doctoral dissertations, two free international MOOC courses have been developed: *Sustainable Energy* and *Sustainable Energy in Education*, which both are also subjects of research. In addition, an international, *virtual Teacher's Climate Change Forum* has been developed. On this forum, teachers are able to share experiences and materials, which they have developed themselves.

Skills in meaningful education of sustainable development

In the promotion of sustainable development and learning its chemistry, the learning of different skills is emphasized (e.g. Eilks, 2015; Juntunen & Aksela, 2014). We have especially researched thinking skills and how to support them in a meaningful chemistry education (Aksela, 2005) and in evaluation (Tikkanen, 2010), central science process skills (Vartiainen, see the article later in this book) as well as in skills of argumentation (Juntunen & Aksela, 2014).

The received research information has been exploited among other things in chemistry teaching and in teacher training, in coming up with the new Finnish National Core Curriculum and in developing evaluation. Concrete examples of thinking skills in a meaningful chemistry teaching have been collected in an article published in a book by the Finnish National Board of Education (Aksela, Tikkanen & Kärnä, 2012).



Figure 5. The ChemistryLab Gadolin (LINKKI) operates as the unit's centre for development and research. There, new pedagogical innovations are developed based on research in cooperation with the department, companies and schools.

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Specialization: teacher training and education in chemistry (30 years' experience in chemistry education; approx. 20 years as an instructor in chemistry teacher education and as a researcher in the University of Helsinki), modelling of chemistry and visualization, sustainable development in chemistry education, inquiry and practical work in chemistry education, ICT in chemistry teaching, project learning in chemistry education, thinking skills and meaningful chemistry education, versatile assessment in chemistry teaching, cooperative teaching, STSE education and science education (non-formal and informal education; 13 years' participation in LUMA science education).

References

- Aksela, M. (2005). *Supporting meaningful chemistry learning and high-order thinking through computer-assisted inquiry: a design research approach*. Helsinki: University Press.
<https://helda.helsinki.fi/handle/10138/21127>
- Aksela, M. & Bostrom, M. (2012) Supporting Students' Interest through Inquiry-Based Learning in the Context of Fuel Cells. *Mevlana International Journal of Education*. (2), 3.
- Aksela, M., Vartiainen, J., Tuomisto, M., Turkka, J., Pernaa, J. & Tolppanen, S. (2016). *Promoting Meaningful Science Teaching and Learning Through ICT in the Finnish LUMA Ecosystem*. Eds. Niemi, H. & Jiyou, J., in a book: *New Ways to teach and learn in China and Finland - crossing boundaries with technology*. (in press)
- Aksela, M., & Pernaa, J. (2013). Kehittämistutkimus pro gradu -tutkielman tutkimusmenetelmänä (Design research as a research method for M.Sc. thesis). Teoksessa J. Pernaa (toim.): *Kehittämistutkimus opetuslalla* (s. 181-200). Jyväskylä: PS-kustannus.
- Aksela, M. & Ikävalko, V.-M. (2016). How to promote relevant practical work through non-formal education? In a book: *Science Education Research and Practical Work*. Ingo Eilks, Silvija Markic & Bernd Ralle (Eds.), Shaker Verlag, Aachen 2016, pp. 131-141.
- Burmeister, M. & Eilks, I. (2013) German Chemistry student teachers' and trainee teachers' understanding of sustainability and education for sustainable development. *Chemistry Education Research and Practice* 14(2).
- Eilks, I. (2015). Science Education and Education for Sustainable Development - Justifications, Models, Practices and Perspectives. *Eurasia Journal of Mathematics, Science and Technology Education* 11(1): 349-358.
- The Finnish National Board of Education (2014). *Perusopetuksen opetussuunnitelman perusteet 2014 (National Curriculum Framework for Junior High School)*.
http://oph.fi/download/163777_perusopetuksen_opetussuunnitelman_perusteet_2014.pdf
- The Finnish National Board of Education (2015). *Lukion opetussuunnitelman perusteet 2015 (National Curriculum Framework for Senior High School)*. Määräykset ja ohjeet 2015:48. Luettu osoitteesta:
http://oph.fi/download/172124_lukion_opetussuunnitelman_perusteet_2015.pdf
- Juntunen, M. & Aksela, M. (2014). Education for sustainable development in chemistry - challenges, possibilities and pedagogical models in Finland and elsewhere. *Chemistry Education Research and Practice*. 15, 4, s.488-500. <https://tuhat.halvi.helsinki.fi/portal/fi/publications/education-for-susta%28d495c322-6396-47a3-bd0d-547b87065878%29.html>
- Ministry of the Environment (2016). A national society's commitment "The Finland we want by 2050":
http://www.ym.fi/en-us/the_environment/Sustainable_development/Societys_commitment_to_sustainability
- Pernaa, J. (2013). Kehittämistutkimus tutkimusmenetelmänä (Design research as a research method). Teoksessa J. Pernaa (Toimittaja), *Kehittämistutkimus opetuslalla* (s. 9-26). Jyväskylä: PS-kustannus.
- Pernaa, J., & Aksela, M. (2013). Model-Based Design Research: A Practical Method for Educational Innovations. *Advances in Business-Related Scientific Research Journal*, 4(1), 71-83.
- Tikkanen, G. (2010) *Kemian ylioppilaskokeen tehtävät summatiivisen arvioinnin välineenä*. (Marticulation exam in chemistry) Helsingin yliopisto. <https://helda.helsinki.fi/handle/10138/21074>
- Tolppanen, S. (2015). *Creating a better world: Questions, actions and expectations of international students on sustainable development and its education*. (Doctoral dissertation).
<https://helda.helsinki.fi/handle/10138/155121>
- Tuomisto, M. Aksela, M. & Jääskeläinen, M. (2015). Osaavia ja ennakkoluulottomia kemian aineenopettajia tieto- ja viestintäteknikkaa monipuolisesti hyödyntämällä (Using ICT to educate skillful chemistry teachers). *LUMAT: Luonnontieteiden, matematiikan ja teknologian opetuksen tutkimus ja käytäntö*, 3 (6).
<http://www.luma.fi/lumat>
- Unesco (2016). *A report: Education for people and planet*. <http://gem-report-2016.unesco.org/en/home/>