Reflexiones

SOCIO-SCIENTIFIC ISSUES AS CONTEXTS FOR RELEVANT EDUCATION AND A CASE ON TATTOOING IN CHEMISTRY TEACHING

Abstract

Context-based science education suggests that meaningful science teaching should be based on the lifeworld, society, or potential professional future of the pupils. But: Are all corresponding contexts for science education similarly good? This paper presents a curriculum model for using socio-scientific issues as contexts for science education in general and chemistry education in particular. It discusses the implications of this approach and presents an example on chemistry teaching about the issue of tattooing.

Keywords: Chemistry Education, Socio-Scientific Issues, Context-based Learning, Curriculum

ASPECTOS SOCIO-CIENTÍFICOS COMO CONTEXTOS PARA LA EDUCACIÓN PERTINENTE Y UN CASO SOBRE EL TATUAJE EN LA ENSEÑANZA DE LA QUÍMICA

Resumen

La educación científica basada en contextos sugiere que para lograr una enseñanza científica significativa deben considerarse aspectos de la vida, de la sociedad, o del futuro potencial profesional de los alumnos. La pregunta es si ¿todos los contextos correspondientes a la educación científica son igualmente buenos? Este documento presenta un modelo de currículo para el uso de temas socio-científicos como contextos para la educación científica en general y la educación química en particular. Aborda las implicaciones de este enfoque y presenta un ejemplo sobre la enseñanza de la química basado en el tema del tatuaje.

Palabras clave: Educación química, aspectos socio-científicos, aprendizaje basado en contexto, currícula

Autores: Ingo Eilks[1], Ralf Marks[2] y Marc Stuckey[3]

[1] University of Bremen - Department of Biology and Chemistry. Institute for Science Education (IDN) mailto:ingo.eilks@uni-bremen.de http://www.chemiedidaktik.uni-bremen.de/, http://www.idn.uni-bremen.de

[2] LIS Bremen - Bremen State Institute for Education. Am Weidedamm 20. 28215 Bremen, Germany.

[3] IGS Wilhelmshaven (Comprehensive School). Friedenstraße 105-111. 26386 Wilhelmshaven, Germany

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SOCIO-SCIENTIFIC ISSUES AS CONTEXTS FOR RELEVANT EDUCATION AND A CASE ON TATTOOING IN CHEMISTRY TEACHING

Introduction

Since the 1970s, science education in general and chemistry education in particular has developed, at least in many Western countries, from teaching isolated facts and theory towards more coherent, student-oriented and context-based curricula (Eilks, Rauch, Ralle & Hofstein, 2013). This development was connected to the growing reception of the theory of situated cognition (Greeno, 1998) which suggests that learning science should start from the life of the learners, society, or any technical and professional applications. Since the 1990s, there have been two major and parallel trends emerging in the international scene of science education: context-based science education and science learning based on socio-scientific issues (SSIs). Both approaches have many commonalities, but also substantial differences (Eilks al., 2013).

Context-based science curricula suggest to start any learning of science from contexts derived from the students' life-world, societal, or technical-professional questions (Pilot & Bulte, 2006). Examples are the Salters chemistry curriculum project from England, *Chemie im Kontext* from Germany, or *Chemistry in Context* from the USA. Context-based science curricula suggest that embedding science learning into contexts will help the students to recognize the meaningfulness of science learning and at the same time to build up applicable knowledge (Eilks et al., 2013).

The other approach, which is often confused with or at least not very clearly distinguished from context-based learning, is socio-scientific issue (SSI) based science education (e.g. Sadler, 2011). Concerning their many different interpretations, one needs to say that both approaches are not always clear to distinct from one to another and sometimes even overlap. However, in detail there are some general differences. One of the differences is the question of how to select the topics and contexts for teaching (Eilks et al., 2013). When we are planning SSI-oriented lessons, the science content is not first, followed by the selection of a context to motivate it and to connect it with meaning. SSI curricula, at least in our interpretation, want to make the context itself (or to be specific: a controversial, science-related concern with societal significance) the subject of instruction. SSI teaching intends to teach the students the necessary techno-scientific base of knowledge to understand the issue, but it also focuses on promoting skills for becoming able to react to relevant queries connected to the corresponding issue and its societal ramifications (Sadler, 2011). By this means, SSI teaching focuses thoroughly on general educational skills, especially empowerment and action skills for participation in society (both in small and at large) (Holbrook & Rannikmäe, 2007).

In the late 1990s, in Germany the so-called socio-critical and problem-oriented approach to science education was suggested starting from a chemistry teaching example on biodiesel (Eilks, 2000; 2002). Over many years of curriculum development and a whole set of more examples a concise curriculum model for dealing with SSIs in a socio-critical

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and problem-oriented way emerged (Marks & Eilks, 2009). Generally, the teaching is organized starting from issues present in authentic everyday media. In the case on biodiesel, we started with advertisements for biodiesel, suggesting arguments for its use (Eilks, 2000). A clarification of the chemical and technical background took place. It covered knowledge and practical work about the synthesis of biodiesel, investigating its relevant properties for technical use, and any technical information to understand biodiesel usage in diesel engines. The knowledge was then reflected on which questions can be answered with this knowledge - and which cannot. The knowledge can help to understand why and how biodiesel can be used as a fuel. However, answering any questions on business and the economy, agricultural issues and environmental impacts, or on related norms and values can only indirectly be supported by scientific knowledge. Furthermore, science in general, or chemistry in particular cannot answer how to weigh and balance arguments from these different domains to one another in order to find an individual and societal position towards using biodiesel as a fuel. All related questions can potentially be better understood by expert knowledge, but the knowledge alone cannot lead to any particular overall assessment or decision. Thus, different perspectives on biodiesel usage from society were then analyzed and compared by the students mimicking - in a role play exercise - a panel discussion of experts from different domains. In the end, the students reflected how much science and science knowledge in such discussions is generally used, who is providing and using - or misusing – it, and how it is connected to the interests of different stakeholder groups. Thus, the lesson plan followed five phases of instruction as they were later presented in the 4-pillars model of our SSI curriculum model (see column 4 in Fig. 1).

Objectives	Criteria for selecting issues and approaches	Methods	Structure of the lesson plans
Allgemeinbildung/ education through science	Authenticity	Authentic media	1. Textual approach and problem analysis
(Multidimensional) Scientific Literacy	Relevance	Student oriented learning and laboratory work	2. Clarifying the science background, e.g. in a laboratory environment
Promotion of evaluation skills	Evaluation undetermined in a socio-scientific respect	Learner centred instruction and cooperative learning	3. Resuming the socio-scientific dimension
Promotion of communication skills	Allows for open discussion	Methods structuring controversial debating	4. Discussing and evaluating different points of view
Learning science	Deals with questions from science and technology	Methods provoking the explication of individual opinions	5. Meta-reflection

Figure 1. The 4-pillars model of the socio-critical and problem-oriented approach to science teaching

In the past almost 20 years, a large number of lesson plans were developed following this curriculum model in a cooperation of science educators and teachers (e.g., Marks & Eilks, 2010). Issues were, for example, critical musk fragrances in shower gels, low-fat vs. low-carb diets, doping in professional and leisure sports, or, most recently, tattooing and hydraulic fracturing. Table 1 provides a selection of lesson plans based on the curriculum model; and it explains how the teaching connected a controversial, societal challenge with corresponding content from the chemistry curriculum.

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Topic	Controversial societal issue	Content
Musk fragrances in cosmetic products	use of risk chemicals in daily-life consumer products	detergents, fragrances, compounds in cosmetic products
Low-fat und low-carb-diets	advertising for and use of different diets among adolescents	chemistry of fats and carbohydrates
Bioethanol	use of food plants to produce fuels and any corresponding environmental and economic effects	chemistry of ethanol and other alcohols
Stevia	controversy in the EU on the approval of stevia as a sweetener for food and drinks	sugar, artificial and natural sweeteners
Climate change	reactions and potential actions towards climate change	air and combustion, chemistry and physics of the greenhouse effect
Doping	control of and punishments for doping in professional and leisure sports	techniques of analytical chemistry
Bio-plastics	properties and sustainability issues of traditional vs. bio-plastics	structure and properties of traditional and alternative polymers
Tattooing	controversy about legislation and the legal age to getting a tattoo	matter, properties and quality control with chemical methods
Natural cosmetics	use of science arguments and misleading claims in advertising	compounds in cosmetic products, preservatives
Hydraulic fracturing	promoting fracturing (like in the US), or not (like in Germany)	chemistry of crude oil and natural gas

Table 1. Curriculum examples of the last 20 years from Germany for SSI-based science education with related content and connections to controversial issues from society

Also, a whole set of new pedagogies was suggested within this approach like, e.g., mimicking the work of journalists, consumer testers, or advertising experts (see below). The historical roots of the socio-critical and problem-oriented approach in German science education and some recent developments are presented in Marks, Stuckey, Belova and Eilks (2014).

In the next section, the curriculum model is discussed in detail and an example is presented on how to operate the suggested framework for SSI-based science education with regard to a recently suggested lesson topic of tattooing in chemistry education (Stuckey & Eilks, 2014).

Socio-critical and problem-oriented science education and an example on tattooing

Objectives

Socio-critical and problem-oriented science teaching, as one form of relevant science education (Stuckey, Hofstein, Mamlok-Naaman & Eilks, 2013), focuses on an *Allgemeinbildung*-centered understanding of science education (see also Elmose & Roth, 2005; Sjöström, 2013). The *Allgemeinbildung* or *Bildung*-oriented understanding of education is a unique central and northern European tradition of conceptualizing all forms of education that in recent years found its way into the international literature in science education under the German term *Bildung* (Sjöström, Frerichs, Zuin & Eilks, 2017). It suggests any kind of education to aim on promoting skills in the young generation for self-determination, participation, and solidarity in a contemporary and democratic society (Hofstein, Eilks & Bybee, 2011). Any corresponding teaching is oriented towards an understanding of fostering education through science learning - instead of a reduced view of the mere mediation of science knowledge through education (Holbrook & Rannikmäe, 2007). The general aim of this way of teaching is multidimensional - or better to say critical - scientific literacy (Sjöström & Eilks, 2018). This view has consequences for both the selection of the content and the pedagogy.

Any restriction of both a rote learning of pure science content and a sole learning about methods and processes from within science will not be sufficient for getting the students to become skillful for participation in socio-scientific debates. Societal-oriented education in science also needs to include learning about science in its broader science-to-society links (Hofstein et al., 2011). Beyond what is important and happens in science, students should be taught about how to evaluate scientific issues and corresponding techno-scientific applications as well as about how it is communicated about science concerning any wider socio-scientific issues involved. That such a teaching also aims on the learning of science content, theories and methods should be self-evident for any science education curriculum model (see column 1 in Figure 1).

With regard to science teaching about tattooing, this means that learners do not only learn about the chemical composition of tattoo inks, their chemical properties, or any physiological risks of tattooing. The students also should learn about the controversial perception of tattooing in public, in our case in Germany, and any corresponding legislation. The students should learn who is setting legal rules on tattooing, e.g. the minimum legal age or restrictions on the dyes to be used, as well as which information, norms and values do play a role in the public and political decision making about. Finally, the students should also develop skills to become able to find their own position towards tattooing concerning their own body and tattoos of others in all the three domains of relevant science education, namely the individual, societal and vocational domain (Stuckey et al., 2013).

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Criteria for selecting issues and approaches

Topics for socio-critical and problem-oriented science education should be authentic, relevant, underdetermined in a socio-scientific respect, openly discussable, and related to questions of science and technology (see column 2 in Figure 1; Marks & Eilks, 2009). Stolz, Witteck, Marks and Eilks (2013) recently suggested corresponding descriptions and ideas of proof of the individual criteria. Table 2 names the criteria and operates them to our teaching example on tattooing.

Criteria	Description and testing	Example "Tattooing"
Authenticity	The topic is authentic, when it is currently being discussed by society. Proof: Common media is checked for presence of the topic, e.g. newspapers, magazines, TV, advertising, Internet, …	Tattoos and tattooing are topics that are generally present in everyday life and the media in Germany. Youth-related media informs the young generation about the latest tattoos of sport, film, music and TV stars. On TV there are even own formats about tattooing and its removal. The Internet documents many controversial aspects of tattooing.
Relevance	The topic is relevant, if respective decisions will affect the current or future lives of our students. Proof: Scenarios on potential decisions are tested to see which impact they will have, e.g., consumer behavior or behavioral choices.	In Germany, the law prohibits tattooing up to the age of 16 with the consent of the parents, and until the age of 18 without their consent. A tattoo at a younger age can have a major impact on career chances, but also on health in the future. A tattoo is also a social statement against others. One wears it for a lifetime.
Evaluation undetermined in a socio-scientific respect	The evaluation allows different points-of-view. Test: Media is analyzed whether controversial viewpoints are represented (by interest groups, the media, politicians, scientists, etc.).	There are very different opinions on tattooing which are also discussed in public. These opinions concern an earlier release of tattooing for young people. Corresponding positions are not infrequently, also a generational question or a question of regional origin.
Allows for open discussion	This topic is able to be discussed in an open forum. Proof: Thought experiments test arguments to make sure that no individuals, religious or ethnic groups would feel insulted or pushed to the fringes of society by their use.	One can openly discuss tattoos. While it is not allowed under certain religious conditions, generally most people in Germany are quite open to like tattoos, or not. Tattoos became more a aesthetic question although question of health and societal acceptability should not be under-emphasized.

Table 2. Criteria for selecting issues and approaches applied to the topic "Tattooing"

Deals with questions from science and technology	This topic concerns itself with a techno-scientific query. Proof: Discourse in the media is analyzed. The question is raised, whether scientific facts and concepts are addressed and either explicitly or implicitly used for argumentation.	Tattoo inks are mixtures of colorants, e.g. pigments, and solvents. The practice of tattooing is related to the structure of the human skin. Possible health risks concern biology and medicine. All these things are referred to in the public discussion about tattoos and corresponding legislations.

Methods

For showing the student the authenticity and relevance of the selected SSI, common everyday media are used for introducing the teaching and learning process (see column 3 in Figure 1). The media generally show that there are different aspects or views available in the public media on how to evaluate the issue. Classic print and news media can be used when they come from the everyday environment of the pupils. However, the media reality of the pupils increasingly takes place on the Internet or in social media. Here one can find reports or opinions concerning corresponding controversies directly from the lifeworld of the learners, e.g. in Internet forums. Information presented in the media can stem both from experts and non-experts and thus needs to be reflected concerning its scientific reliability as well as the corresponding interest behind any author and his intentions to bring any information into debate.

For better understanding the need to learn about media in the public, the idea of filtered information was proposed by Hofstein et al. (2011) and later expanded by Stuckey, Heering, Mamlok-Naaman, Hofstein and Eilks (2015) with connection to the here presented curriculum model. The idea of filtered information is about understanding the way of how scientific information finds its way from science into everyday media and communication. Information from science to the public is passed on by persons (science authors, journalists, politicians, advertisers, …) and thus always changed and often simplified or re-interpreted ('filtered') in each single step of transfer. In the result, sometimes it becomes similarly important to understand the intentions of any provider of information and the processes of the information use, than to be able to estimate the scientific reliability of any piece of information itself (Stuckey et al., 2015). A way to promote understanding how scientific information is transferred and used in society can be imitating corresponding practices. We call this the "mimicking of authentic societal practices of science-related communication and decision-making processes". Potential pedagogies are, e.g. structured controversies, role plays, or business games. However, new methods developed in the framework of this curriculum model can also encompass writing newspaper articles like a journalists (Marks & Eilks, 2010), conducting simple product test reports (Burmeister & Eilks, 2012), creating advertisings (Belova & Eilks, 2015), or building up threats in Internet forums (Dittmar & Eilks, 2016).

In our example on tattooing, we suggested to begin with a self-test inspired by a German youth magazine. The students perform such a test as an authentic societal practice. They were asked to reflect from which domains the question of the self-test were coming from and how many - or few - scientific aspects do generally play a role in

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such a test. The items in the test motivated questions towards the science of tattooing that were to be clarified. However, science can only be related to part of the questions. Thus, the students also started to search the Internet for any views or legal restrictions on tattooing from within society. The final activity in the lesson plan was again inspired by an authentic societal practice of communication and decision making. The students got the task to respond to a fictive student's letter to the question-answer format of a youth-magazine. They had to give advice to a 16-year old student who wanted a tattoo but his parents did not allow. The students had to decide whether to use arguments from science for their answers, which arguments, or not to use scientific information at all. In the reflection it got clear that in the authentic media it is the editorial team who decides on the use of science in such issues and it was also discussed that editorial teams of youth-magazines generally shall not be composed of many scientists.

Structure of the lesson plan

From the many teaching examples developed, it turned out that the lesson plans according to the socio-critical and problem-oriented curriculum approach almost always follow a generally similar structure (see column 4 in Figure 1). The access to the lesson plan takes place via authentic media from the pupil's lifeworld, which are used either unchanged, in extracts, or adapted. There is a second phase of clarifying the scientific and technological background, e.g. by practical work. A first reflection of the issue shows that science can only answer a part of the relevant questions. Comparing different perspectives from within society on the issue makes clear that in SSIs also opinions, values and norms flow in. Finally, a reflection on how the debate is influenced by individuals and what role science-related information plays is suggested to contribute the development of students' skills for self-determination and societal participation. Table 3 suggests a lesson plan on the example of tattoos might look alike (Stuckey & Eilks, 2014). Figure 2 gives a few impressions from the practical work in phase 2.

Step	Activity	Explanation
Textual approach and problem analysis	The learners perform a self-test on their attitudes towards tattooing. Views and arguments for and against tattooing are collected and discussed.	The self-test is based on an authentic test of a German youth magazine. The questions are reflected whether they address individual-aesthetic, societal, or medical-scientific aspects.

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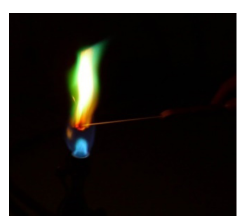
Clarifying the science background, e.g. in a laboratory environment	In a laboratory environment, the students investigate and compare tattoo inks (those under German law, and cheap alternatives from the Internet). The students also learn about health and legal aspects as well as issues of tattoo removal.	There are tattoo inks according to the German tattooing regulations compared to much cheaper ones, which can be ordered from the Internet. The exact origin, composition and quality of the Internet inks is often unclear and partly questionable.
Resuming the socio-scientific debate	The clarification of the scientific background is reflected with respect to where it was helpful to understand aspects of the controversy - and where not.	The students recognize that science can only answer questions on the ink quality and potential health risks. It cannot answer whether someone likes a tattoo and at what age tattooing should be considered legal.
Discussing and evaluating different points of view	The pupils answer a letter of a teenager to the editorial department of a youth magazine, who wants to be tattooed, but whose parents do not allow this.	The students work in small groups. They need to decide whether to draw on medical or scientific aspects to answer the student‘s letter, or not.
Meta-reflection	The writing exercise and the use of arguments are reflected.	The pupils recognize the extent to which the editor influences the direction of the response to the fictive student‘s letter and also on whether scientific aspects are used, which of them, or none at all.

Table 3. Course of the lesson plan on tattooing

Garden cress exposed to red tattoo ink

Thermal stability of different red tattoo inks



Flame-colouration by a blue tattoo ink

Conclusion

Education in general and science education in particular are subject to ever-changing challenges. One of the biggest challenge might be to educate the future generation for a self-determined and responsible life in the future in a continuously changing and more and more techno-scientifically dominated world (Elmose & Roth, 2005). Knowledge and understanding of science is crucial for our all future making science education relevant in a set of different dimensions, namely the individual, societal, and vocational life of the students today, and in the future (Stuckey et al., 2013). However, a self-determined and responsible life in our modern society needs more skills, e.g. skills in coping with the media (Eilks, Nielsen & Hofstein, 2014). The ever appearing changes ask for developments in science education – beyond just changing the content or only framing it differently by contexts that are not relevant for the students' life or future.

Questions such as education for sustainable development were hardly the focus of science teaching a few decades ago. This is different today. Critical media education, too. Before the introduction of the Internet and the associated, permanent change that it undergoes it was much more manageable to cope with the media landscape that underwent much less and slower changes than today. Also issues of professional orientation, the preparation for appropriate training courses, and the challenges of lifelong professional learning became increasingly complex and unclear. This list could be continued as desired. Science education needs to find answers about its potential contribution to these many cross-curricular challenges (Belova et al., 2017) and operating SSI-based science instruction might be one answer for this (Stuckey et al., 2013).

To us, science education should more thoroughly raise its potential to promote general educational skills. We see SSI-based science education as one of the most promising approaches that might lead to more than content learning and contextual understanding, but might promote the development of critical scientific literacy as suggested by Sjöström and Eilks (2018). The socio-critical and problem-oriented curriculum model as presented here attempts to contribute to this. Many case studies demonstrated its rich potential and promising influences on students' motivation, their views towards science, and their positive overall reception of the lessons (e.g. Eilks, 2002; Marks, Bertram & Eilks, 2008; Stuckey & Eilks, 2014). Science education in general, and chemistry education in particular, should deal with societal controversies on a large scale, such as climate change, or on a small scale, as it is the case with the issue of tattooing. Students should get a chance to learn not only the content behind any societal controversies; they should learn in science classes *how* to discuss about science, *how* to make and influence informed decisions in society about techno-scientific queries, and which role science-related information may play in their lives. This is a societal and much more multi-dimensional view on science and chemistry teaching that is still too often neglected in current science curricula (Hofstein et al., 2011).

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