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Increasing student motivation and the perception of chemistry's relevance in the classroom by learning about tattooing from a chemical and societal view

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This paper presents a study on tattooing as a topic for chemistry education. The selection of the topic was inspired by a newly suggested framework, which focuses on the question of relevance of science education. The aim of this case was to get evidence on how topics selected based on the suggested model of relevance of science education affect learners' overall motivation and perception of chemistry learning. For the purpose of the study a lesson plan was cyclically developed and tested within a project of Participatory Action Research. The lesson plan focuses both the chemistry behind tattoo inks and the societal perspectives surrounding tattoos. The study description first includes some background information about tattooing and tattoo inks. It then continues with a description of the lesson plan and ends with reporting experiences and findings taken from lesson plan evaluations at the lower secondary chemistry teaching level (age 14–15). The topic and lesson plan proved themselves to be very motivating for students. Indicators that this lesson plan can potentially contribute to positive changes in students' perceptions of learning chemistry were also observed. Implications arising from this case are also discussed.

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Introduction

For decades science education in general and chemistry education at the secondary school level in particular have both been continually described as being not very popular among students (Holbrook, 2008; Osborne and Dillon, 2008; Hofstein *et al.*, 2011). The reason for this is very often cited as a lack of student perception of the relevance of science learning for their life. This in turn results in low levels of both interest and motivation in science learning (Osborne, 2003; Jenkins and Nelson, 2005; Holbrook, 2008). Consequently, science teachers are constantly upbraided to somehow make their science teaching more 'relevant' (Newton, 1988; Holbrook, 2005). However, it is often not very clear what the mantra 'making science education relevant' actually means (Stuckey *et al.*, 2013), nor is it clear how exactly teachers are to select suitable topics for approaching and contextualizing chemistry learning in the most relevant and motivating fashion (Gilbert, 2006).

This paper operationalises a newly suggested theoretical framework. This framework reorganizes the different understandings and dimensions of the relevance of science education. It was derived from a broad hermeneutical analysis of the science education literature of the past 50 years and is justified in detail by Stuckey *et al.* (2013). Using this framework as a foundation, a lesson plan was developed focusing on both the chemical aspects of tattoo inks and the societal and vocational issues surrounding the practice of tattooing. The individual lessons employ inquiry-based experiments, newly conceived pedagogies derived from youth media in order to initiate theoretical and practical learning, and also learner self-reflection on their individual view on tattoos and tattooing.

The lesson plan was developed within a project of Participatory Action Research in science education (Eilks and Ralle, 2002). After pre-testing was carried out in different learner groups, final implementation of the teaching unit was undertaken in five 9th-grade classes (age range 14–15) in a comprehensive school in northern Germany. A case evaluation investigated any potential effects which the lesson plans had on students' overall motivation and their perception of the relevance of learning chemistry.

Theoretical framework

The term 'relevance' and the perception thereof are often-used elements of rhetoric when speaking of reforms in both science and chemistry education (Newton, 1988). However, analyzing research and political papers in science education clearly

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reveals that 'relevance' itself is a highly relative word (Stuckey *et al.*, 2013). It is usually unclear exactly what authors mean when demanding that teachers make their science teaching more 'relevant' for their students. Different authors define and use the term in quite obviously different ways. Based on a thorough analysis of the literature, Stuckey *et al.* (2013) described the different meanings. In the literature, the word relevance is often suggested either as a synonym for students' interests (Childs, 2006) or as a measure of their personal perception of meaningfulness (Westbroek *et al.*, 2005). Other published understandings base their definition of what truly constitutes 'relevance' on such widely diverse factors as meeting students' needs (Keller, 1987), somehow connecting relevance to true and potential real-time changes and developments within the learners' personal life and society (Stolz *et al.*, 2013) – or any combination of all of the above concepts.

Based on a broad hermeneutical analysis from the literature in science education from the last 50 years, it was found that the term 'relevance' in science education is used manifold and includes aspects like satisfying students' interest, raising motivation, or the development of attitudes. However, other uses of the term were also found, that go beyond these constructs. Based on all the ways 'relevance' is interpreted in the science education literature, Stuckey *et al.* (2013) suggested to understand the term 'relevance' in terms of consequences. From the analysis of the literature it was also derived that 'relevance' in science education has different dimensions, what is also suggested in *e.g.* Newton (1988) or van Aalsvoort (2004). The consequences of (not) learning science, or chemistry in particular, can occur both in the present and in the future of the learner. It is also highly likely that many concrete consequences reach far beyond what students perceive as personally interesting or individually motivating. This leads to further extrinsic aspects of the relevance of science education. As one widespread example, many parents and school systems commonly want children to take a broad range of courses (even if the learner is uninterested in them) in order to provide the best possible chances for further education in the future or a broader spectrum of possible career options. It was also found that the understanding of what constitutes relevance can be characterised by three dimensions: individual, societal and vocational relevance. However, it should be mentioned that these dimensions are neither dichotomous nor hierarchical. But, the dimensions seem to be comprehensive. They cover the debate in science education for almost the last 50 years. Also a recent focus group study showed comprehensibility of the suggested model. This study was done with science education experts of different degree of expertise (from student teachers, *via* teacher trainees, towards leading teachers and science educators). In none of the expert focus group discussions aspects were suggested that were not fitting the hermeneutical derived model (Stuckey *et al.*, 2013). By using earlier published suggestions on the topic of relevance in science education, Stuckey *et al.* (2013) finally proposed a three layered model for operationalising the different dimensions of relevance as illustrated in Fig. 1. For a more detailed description of the theoretical background and the model on relevance see Stuckey *et al.* (2013).

The model as illustrated in Fig. 1 provides a helpful tool for reflecting upon the nature of current science curricula, textbooks and teaching practices. Using this graphic we can begin to reflect whether science class includes a balanced

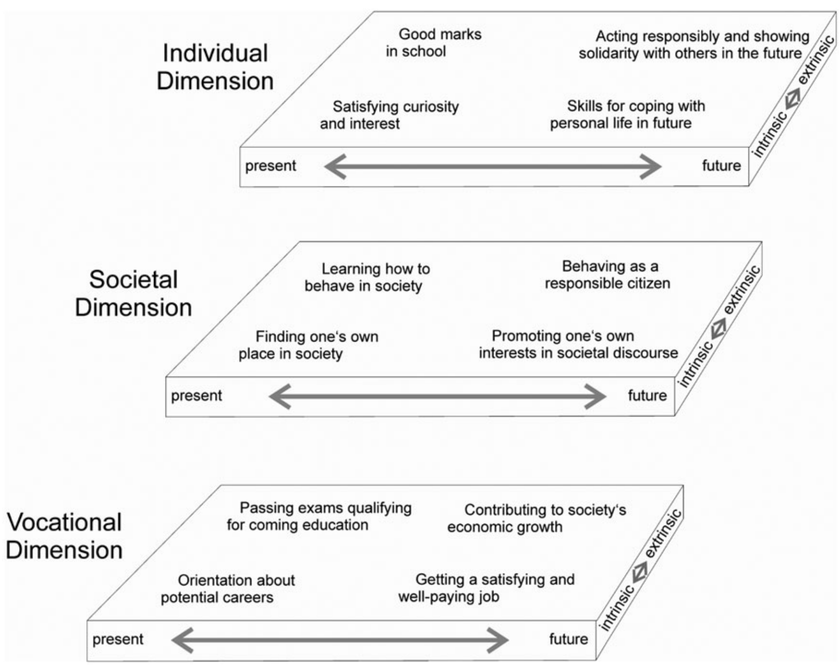

Fig. 1 An illustration of a suggested model for the relevance of science education with its individual, societal and vocational dimensions, including examples illustrating the present–future and intrinsic–extrinsic ranges involved (Stuckey *et al.*, 2013).

offering of all of the potential dimensions with regard to both specific groups of students and their age level. Even though it may not be possible to satisfy all of these aspects during all parts of the curriculum, this model can be used to search for solutions addressing at least some of the needs found. Lesson plans can contribute to covering many of these aspects in various ways at different phases of the science curriculum. However, maybe it is also possible to select topics that explicitly deal with all the three dimensions at once and also encompass aspects relevant both for the students' present lives and their future.

The described framework gave the idea of searching for multidimensional topics covering all three dimensions of relevant science education in a balanced way to increase student motivation and to raise their perception of relevance of chemistry learning. One example of this might be found in the practice of tattooing. Tattoos are a chemistry-related issue and a current aspect of youth culture and the general media. The high-profile presence of tattooed athletes, pop stars and other celebrities on TV and in youth magazines confronts pupils with the decision of getting their own personal tattoo (or not). It also demands a personal reaction to other peoples' tattoos and an opinion about the individual decision to get body art. The decision to get a tattoo is not just an aesthetic one. It also includes health risks with potentially long-term effects. Tattooing also possesses present and future societal implications. Body art can represent a visible social statement, in very extreme cases up to and including an implicit rejection of mainstream society and its views. This in turn can have individual consequences in situations where other people do not share the same views. In many societies, tattoos are still rejected by certain people and individuals with tattoos are still sometimes stereotyped and discriminated against. Body art also presents society with more general questions. For example, should insurance companies ever pay for tattoo removal due to health problems out of communal funds, since the decision to get a tattoo is generally considered a personal affair? Tattoos also have present and future vocational implications. They can possibly turn an individual's decision to 'be different' or to 'express oneself' into a concrete consequence which the general public is not willing to condone. In some countries it is generally more difficult to find a good-paying job in many branches of work such as banking, public services, insurances, or public relations, if the employee is covered in visible tattoos. However, learning about tattoos also offers career orientation and career chances. Not only tattoo artists, but also medical staffs and technicians are forced to deal with health problems arising from tattoos, or tattoo removal with laser beams. In this respect, tattooing offers present and future aspects in all three dimensions of relevance, including the extrinsic and intrinsic components. This makes the chemistry related issue of tattooing relevant to pupils' life worlds and the societies in which they live, especially in most Western countries (Fig. 2).

Background information

Tattooing has had a very long history around the world (Hambly, 1925). For example, when the mummified Tyrolean man nick-named "Ötzi" was discovered in the early 1990s on the Austro-Italian border, his body was found to be covered with more than 50 tattoos. And "Ötzi" was estimated to have lived roughly 5300 years ago (Pabst *et al.*, 2009). This is just one example proving that people have experimented with introducing colour under their skin for hundreds or thousands of years. This occurred for a variety of reasons, be they cultural, religious or simply aesthetic.

Until a few decades ago, only small sections of the Western society allowed themselves to be tattooed (some minorities or groups such as sailors, prisoners, *etc.*). These people were generally stereotyped and, even today, sometimes discriminated against (Meier, 2010). However, tattoos have become increasingly accepted in the past few years, because they have become

Individual relevance

- A tattoo is a lifetime decision with aesthetic implications and potential health risks. Students have to find their position for or against it.
- Many idols of the young generation wear tattoos, maybe even friends and family. Students have to decide how to react: to follow, object or abstain.

Societal relevance

- Tattoos can represent a visible social statement. The statement will provoke reactions by the personal environment and the society.
- Society has to decide about, e.g. limiting the minimum age for tattooing, regulating tattoo products and practices, or covering any costs by public health systems caused by tattoo making or removal.

Vocational relevance

- There are many professions concerned with tattoo making, tattoo-related health risks, or tattoo removal.
- Visible tattoos can limit career chances, e.g. in the bank or insurance sectors.

Fig. 2 The relevance of the chemistry-related issue of tattooing.

fashionable throughout all sections of many, at least many Western, societies.

For years the overall number of tattooed adolescents has increased (Armstrong and Murphy, 1997; Brähler, 2009). In the Western world today, more than 100 million people have tattoos (Vasold *et al.*, 2008). In Germany, it is estimated that about 10% (8 million) citizens are tattooed (Down, 2011; Lehner *et al.*, 2011). In the UK and the US the levels are over 20% (Laumann and Derick, 2006; Henley, 2010; Braverman, 2012). Among young people the rate is higher than among adults. In Germany more than 20% of teenagers and people in their early twenties (age 14–24 years) have a tattoo (Brähler, 2009). In the US 36% of people in the age range from 18–25 have tattoos (Pew Research Centre, 2007). In Germany the numbers have increased dramatically in recent years, particularly among women. Tattooing does not appear to be a gender-specific topic any more. Data show that tattooing is just as popular with men as it is with women (Brähler, 2009).

Motivations for getting a tattoo are often linked with marking one's personal individuality (Antoszewski *et al.*, 2009). Popular musicians, actors and athletes, for example, help promote this trend, because they are the idols of today's youth (Armstrong and Murphy, 1997; Bush *et al.*, 2004). Young children are also influenced by cartoons in which the comic figures are tattooed (*e.g.* in the US-cartoon "Stoked"). Today's youth media, the yellow press and even serious magazines (Time Magazine: Finan, 2002; BBC: Townsend, 2011) and TV programs include reports about tattoos.

Individuality, fun, acceptance into a well-defined group, peer pressure and isolation (Antoszewski *et al.*, 2009) are all as intimately linked to tattooing as the health risks, legal regulations and high costs for tattoo removal. Health risks are generally associated with infections caused by unsterile tattooing equipment and include such diseases as hepatitis or HIV (McCormack Brown *et al.*, 2000). However, the inks themselves can potentially harm the human body. The component parts making up the ingredients for different ink colours may include heavy metals and many aromatic compounds, which can affect health negatively and promote allergic reactions under the skin (Papameletiou *et al.*, 2003; Schmitz and Müller, 2004).

Such problems are exacerbated in many countries through the lack of meaningful, effective regulations, an acceptance of questionable tattooing practices and desultory controls of acceptable tattooing agents. There are currently no common regulations on tattooing at the international level. All legislation related to the component parts of tattoo inks are simply based on national laws or directives. Because of this, Germany has instituted legislation since 2009 which limits the number of allowable compounds in tattoo inks and provides clear guidelines for comprehensive product labelling. Irregardless of this move, it is still possible for Germans to order all varieties of tattoo inks *via* the Internet, which stem from foreign countries in which national laws are either nonexistent or are not particularly strict.

Consumer tests of different tattoo inks have shown that many foreign products do not comply with strict quality regulations regarding tattooing under German law (CVUA Karlsruhe, 2011). In 2013, a German product testing magazine analyzed twenty tattoo inks which were being used in German tattoo parlours (10 black inks and 10 coloured ones). Fifty percent of the coloured inks and 20% of the black inks did not pass muster. One out of five of the coloured products was found to have been highly contaminated by aromatic amines, PEG's or PEG-derivatives, heavy metals or halogen-organic molecules (Ökotest, 2013). A Swiss study also showed that 80% of the tested tattoo inks used did not satisfy the national requirements (Bundesamt für Gesundheit, 2009). Most of the black inks tested included phenol and other hazardous polycyclic aromatic hydrocarbons, all of which are carcinogenic (Regensburger *et al.*, 2010). Other investigations revealed that some black tattoo inks contain hexachloro-1,3-butadiene which is genotoxic *in vitro* (Lehner *et al.*, 2011). Even more ominous is the fact that only a small portion of the tattoo inks available on the market has been tested in all these studies. The variety of available inks is so enormous that it is impossible to check every product for safety due to the time involved and the high costs of analysis. In Germany, consumers are only minimally protected by law, because serious tattoo parlours let their tattoo inks be tested by independent institutes. These institutes then issue a certificate listing all of the ingredients, which the consumer can request to view. However, many potential customers are not aware of this particular right because they are poorly informed.

More chemical-related risks emerge whenever an attempt is made to remove a tattoo. Laser treatment can split the inks to smaller chemical compounds, but it is often unclear exactly which by-products will be produced as a result. This makes it next to impossible to rule out the chance that the resulting substances will not be harmful, too. Research has suggested, for example, that laser-induced splitting of azo-based dyes provokes carcinogenic amines (Papameletiou *et al.*, 2003). Other problems connected to the removal of tattoos by laser treatment can arise if the wavelength is incorrect. This may cause the destruction of body pigments and generate local pigment disorders. However, scars can also develop as a result of using laser treatment to remove tattoos (Alster, 1995).

Development of the lesson plan, method and sample

The development of the lesson plan followed the model of Participatory Action Research in science education (PAR). The model was proposed by Eilks and Ralle (2002) and has been tested in many studies with respect to its potential for evidence-based curriculum design (Marks and Eilks, 2010; Eilks and Feierabend, 2013). It has also been evaluated for its potential to change classroom practices and for its impact on continuous professional development for teachers (Mamlok-Naaman and Eilks, 2012; Eilks, 2014).

PAR is a collaborative process of curriculum design and classroom-based research in which educational researchers and in-service teachers cooperate. In doing so, PAR is a strategy of design-research based on action research principles (Eilks and Feierabend, 2013). The major difference compared to other design-research methodologies lies in the involvement of teachers in all decisions concerning the design, their participation in all activities of research and teaching, and the clear intention from the beginning of changing their concrete teaching practices. In the cooperation of teachers and external researchers, PAR combines both evidence-based knowledge from educational research and practical, hands-on experiences in classroom settings, both of which are important aspects of the knowledge spectrum for teaching and learning with their own strengths and weaknesses (McIntyre, 2005). The evidence gathered from educational research and teachers' practical experience is united through both analysis and group discussions. Within teacher–researcher group processes, knowledge from the different domains is compared and reflected upon with respect to its relevance for innovation in teaching practices. Using this as a starting point, teachers and researchers cooperate to develop and investigate new science teaching practices.

The development and research is a cyclical process (Fig. 3). In the PAR model, lesson plans are drafted, tested, analysed and then revised. Focal points – as is the case in any type of Action Research – include the improvement of authentic teaching practices and contributions to the practitioners' continuous professional development. PAR also aims at disseminating innovative teaching concepts and materials, including reports of empirical evidence regarding their effects in the classroom. The accompanying research focusses on both any personal perceptions expressed by the participating teachers and learners as well as selected effects caused by the changed teaching strategies (Marks and Eilks, 2010).

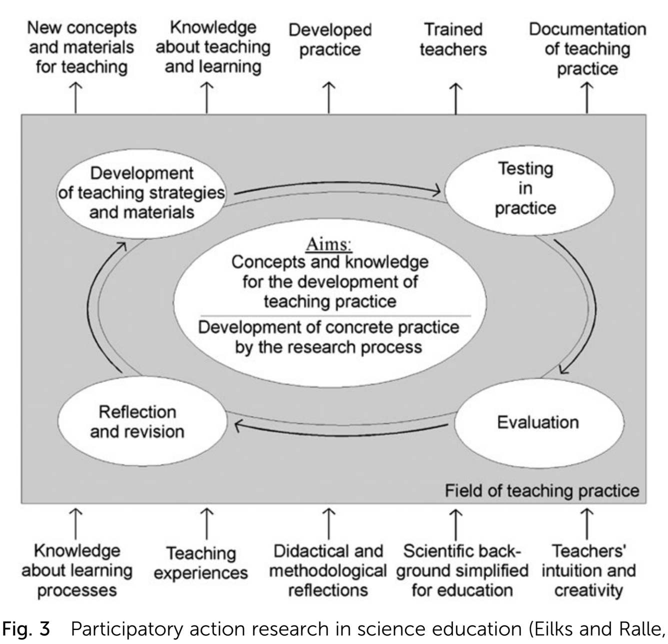

Fig. 3 Participatory action research in science education (Eilks and Ralle, 2002).

The lesson plan on tattooing was developed by a group of eight teachers from different schools in western Germany, who have now worked together for over 15 years (Mamlok-Naaman and Eilks, 2012). Teachers and researchers meet regularly once a month for a whole afternoon. For this particular topic, the teachers and science educators worked for about a year on the lesson plan. New in-school, hands-on experiments were developed and tested. Changed pedagogies were discussed in the group and then developed for active classroom use. Pre-testing of the materials took place in three upper secondary school chemistry classes (age 17–18 years), before a lesson plan for 9th-grade chemistry classes (age range 14–15) was finally structured.

At the end of the development process a broader evaluation study was carried out in five 9th-grade learning groups. The students were informed that they are participating in a study on innovations in the chemistry curriculum. A total of 118 pupils took part in the lessons. All of them came from a comprehensive school in northern Germany. Feedback was collected using classroom observations by the teacher and student questionnaires. Two questionnaires were utilized. The students were asked to provide feedback on a voluntary basis. The first questionnaire focused on the students' opinions of the feasibility of the lesson plan and their personal perceptions regarding the topic and the applied pedagogies. This questionnaire was made up of three open questions and 10 Likert-items (four-point) on the perception of different aspects of the lesson plan. Feedback for this part was given by a total of 95 learners. A second questionnaire was applied both before and after the lesson plan in order to note any changes in learner motivation (feedback from 108 students). The MoLE (Motivational Learning Environment) questionnaire focuses on pupils' perception of their chemistry education both before and after the lesson plan is carried out. It also asks about the learners' wishes for future chemistry education prior to the intervention (Bolte *et al.*, 2013). The MoLE-instrument was developed by Bolte (2006) on the basis of different theories of interest and motivation. It consists of 14 items in 7 scales representing different aspects of motivation: subject relevance, subject orientation, comprehensibility, satisfaction, willingness to participate, class cooperation, and opportunities to participate. All items are to be reflected upon by the students and recorded on a seven-point Likert scale. The instrument was tested with a total of 4468 students. The quality of the instrument was checked for reliability by Cronbach's alpha (between 0.59 and 0.82) and for construct validity by factor analysis (strong validity of all constructs) (Bolte, 2006). In the current study the MoLE questionnaire was used to investigate any effects that this lesson plan had on the learners' level of motivation. Differences in perception prior to the lesson, including those concerning earlier learning experiences in former chemistry lessons were examined. This also included the students' wishes for what they viewed as 'ideal' chemistry lessons. These two factors plus the learner reflection carried out after completion of the lesson plan on tattooing were then analysed using *t*-tests. All calculations were performed using SPSS.

Table 1 Overview of the lesson plan on tattooing

Step	Task
Textual approach and problem analysis	– Mimicking a self-test page from a commonly known youth journal (''What kind of tattoo person am I?'') – Reflection on the different perspectives found in the self-test: aesthetic, societal and science-related – Developing specific questions asking about the chemistry background of the topic
Clarifying the chemistry background in a lab environment	– Carrying out various inquiry-based experiments on tattoo inks with different origins (learning-at-stations)
Re-examining the socio-scientific dimension of the topic	– Reflecting upon which scientific aspects of the topic were answered in the laboratory phase and which were not
Discussion and evaluating different points of view	– Mimicking the editorial consulting function found in youth journals by responding to a fictitious letter from a teenager who wants to get a tattoo – Presentation of the various replies to the letter and reflection on why chemistry-related arguments were or were not chosen
Meta-reflection exercise	– Reflection upon exactly which role science-related information plays in the youth media with regard to both self-tests and consulting readers

The lesson plan

The lesson plan is composed of four lesson periods each 45 minutes long. It is structured along the lines of the socio-critical and problem-oriented model of chemistry education as outlined by Marks and Eilks (2009). The unit follows the following five-step model: (1) a textual approach with problem analysis, z(2) clarification of the chemistry background in a lab environment, (3) re-examining the results in the light of the socio-scientific dimension, (4) discussing and evaluating the different points of view which arise in the socio-scientific debate, and (5) carrying out a meta-reflection exercise afterwards. An overview is given in Table 1.

Textual approach and problem analysis

We decided to start with media which are embedded in everyday life in order to give a more authentic feel to the lesson plan to the students. Learners with a target group age of roughly 12–16 years have already experienced a great deal of exposure to tattooing in magazines and TV programs aimed at young people. These magazines present pictures showing the latest tattoo acquisitions of musicians, actors and sports stars. One very common practice can also be found in these magazines: self-tests in which the reader has to answer 10–20 multiple choice questions. A certain number of points are awarded for each answer. The final score is supposed to represent a specific point-of-view of the reader, which allows the reader to find out which group suits him or her best. One such test was published in a popular, online German youth magazine, Bravo, which asked the question: 'What kind of tattoo person am I?'

The teaching materials were developed based on an analysis of this self-test. In the original test we found that the individual perspective had been selected as the most relevant aspect of young people's viewpoints on and decisions about tattooing (test available at: http://www.bravo.de/lifestyle/liebe-leben/welcher-tattoo-typ-bist-du/ex/page/0). Using this magazine as a template, we constructed a fictive test similar to the one found in the Internet survey. Further perspectives were also added, based on the model of science education relevance published by Stuckey *et al.* (2013). A total of 14 questions were devised, which focus on pupils' aesthetic and personal opinions about tattoos, a consideration of the societal aspects of wearing tattoos, relation to potential careers and the workplace, as well as arguments dealing with both healthy effects and risks if getting a tattoo. Example questions are given in Fig. 4. Each question offers three multiple choice answers ranging from 0 to 2 points. The final result after adding all the points provides an estimate of the test person's personality: ''You reject tattoos.'', ''You are undecided, but curious.'' or ''You are very interested in tattoos.''

During the lesson the discussion eventually leads to the question of where and exactly how much science- and chemistry-related information is presented in such self-tests. Self-reflection among the learners is introduced by implying that other factors besides science and chemistry are used to answer how a person forms a personal opinion on tattooing. Science can only supply information about the physical ingredients of the inks, how they react with the human body, *etc.* The final decision to get a tattoo, however, is also influenced by both aesthetic considerations and the social environment in which the learner is embedded.

Clarifying the chemistry background

In this phase the students inquired into the toxicity, stability and other physical properties of tattoo inks (Stuckey and Eilks, under review). The students performed several experiments which compared expensive tattoo inks produced and certified under German law with cheaper products purchased abroad *via* the Internet. The certified inks were all from the brand name Sailor Jerry. These inks are fully labelled with all required legal information. The price is generally about €6 for a 10 mL bottle. The cheap alternative was the brand Tattoo Specific Color, which was ordered from an Internet warehouse in Hong Kong. The overall price was €24 for 9 bottles of different inks containing 30 mL each. For these inks almost no information about the compounds is presented on the label. There is no expiration date or any type of other safety information listed. The differences in price and information available offers an excellent opportunity to structure the inquiry-based learning phase, while simultaneously making such product differences an explicit part of the teaching and learning process.

The learning-at-stations method (Eilks, 2002) was chosen to integrate the practical work with theoretical learning (Table 2).

1	*Many celebrities are tattooed. What do you think about that?*	Points
A	I don't like it!	
B	Fantastic! Tattoos look great.	
C	I don't pay attention to tattoos.	

...

5	*Tattoo inks include pigments that are also used in car paint. Were you aware of this?*	Points
A	Yes. But it irritates me that tattoo ink and car paint have the same ingredients.	
B	This is nonsense! I think this is a scare tactic to keep people from getting a tattoo.	
C	I don't know. I can't say anything about the subject.	

...

13	*Salesmen with tattoos on their arms have to wear long-sleeve shirts in the summer.*	Points
A	This is good, because they are in contact with customers, e.g. when they advise somebody.	
B	This is ridiculous. Today tattoos are accepted by everyone in society.	
C	This makes life difficult. Many people and businesses still do not accept tattoos in the public or professional arena.	

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Fig. 4 Examples for personal (1), scientific (5) and societal (13) questions about tattooing in a fictive self-test.

Table 2 Some potential tasks for learning-at-stations with different tattoo inks

Flame coloration test: detecting and determining the identity of metal atoms *via* a flame coloration test. For example, blue tattoo inks produce a green flame, which may indicate the presence of copper ions.	Particle size: the particle size of different tattoo colours is investigated using a microscope. Cheap tattoo colours often have much smaller particle sizes on average than certified colours.	Enzymatic activity: potatoes are cut into pieces of the same size then exposed to different tattoo inks for several minutes. They are then placed in 5% hydrogen peroxide solution. Contamination with ink reduces the enzyme activity of the potato's enzyme, catalase.	Colour index: students learn about the colour index and search for the colouring compounds for those inks that are sufficiently labelled.
Stability of tattoo colours: several drops of tattoo ink are heated for a few minutes. Some inks remain unchanged, others decompose.	Solubility: the solubility of tattoo inks in water, ethanol, and oil is tested. Most of the colours dissolve or disperse well in water.	Living organisms: garden cress is watered with diluted solutions/dispersions of different tattoo inks (pure water as a control). The colours cause limits in cress growth or even lead to death.	Formal regulations: students learn about government regulation of tattoo inks and compare different brands to these labelling regulations.

The students quickly discover that there are huge differences between the inks from different manufacturers. For example, the particle size of cheaper inks seems to be smaller on average. This may increase the mobility of pigment particles in the human body. The thermal stability also tends to vary widely. Cheaper inks sometimes decompose when heated. In the human body this might lead to a colour change, if the pigments are exposed to strong sunlight or radiation. The information content on the labels was also questioned by the students. Flame coloration tests indicated that many heavy metal ions were found in the pigments. Whenever sufficient labelling was available, this step was combined with an Internet search that was based on the given colour index. Without sufficient labelling, this step was merely an indication that undisclosed substances were present in the inks.

It is important to mention that this comparison does not mean that German or EU products are any better or worse than Asian products. The testing only provides a comparison of different tattoo inks. Other brands or inks from other countries may offer totally different results.

The experimental stations are also supported with theoretical stations. One of these deals with German laws for tattoo inks, declaratory documentation, and reference to the colour index. Another provides learners with information about the removal of tattoos with the help of laser beams.

Resuming the socio-scientific dimension and reflection

After learning about the chemical background of tattooing and tattoo inks, pupils are asked which of the original questions in the self-test can be answered solely with chemistry knowledge and which cannot. It rapidly becomes apparent that questions about health risks and preventive measures can be better answered with a deeper knowledge of inks and their specific interactions with the human body. However, personal and societal arguments also play an important role. In order to reflect upon this balance, the youth magazine aspect is taken up again. Pupils are provided with a worksheet with a fictitious letter from a teenager who wants to get a tattoo, but whose parents are against the idea. The students must now step into the role of a professional consultant who writes editorials in the advice column of the youth magazine. A short and comprehensive answer is demanded from them. All of the responses are compared before the pupils reflect upon how, when and why they made use of the content knowledge which they learned in class.

Meta-reflection

Finally, a discussion is introduced which looks at whether or not arguments from chemistry and science are used by youth magazines. This includes the question of why such evidence is so often left out or ignored. A further reflection on how individual, societal and scientific information and arguments are used and balanced is also undertaken. The learners are asked to formulate their own opinions as to whether or not the facts and findings of science should be more often used when informing the public about personal issues such as a decision to wear a tattoo. The students should understand that science can partially help in making a decision in the case of open, multidimensional questions. However, each person must eventually make a decision based upon a balance of arguments borrowed from the various dimensions according to his or her own interests and opinions.

Findings from the case evaluation

Feedback from the teachers

Based on classroom observations this lesson plan was described as being highly motivating. The self-test was considered as very authentic and motivating as a pedagogical method. Intense discussions among the students were reported in every case. The participants fulfilled the tasks and were also able to categorise the questions related to the different dimensions of the test. Teachers described feedback from the students that they had enjoyed the investigations into tattoo inks and that they were very interested in the inherent risks. Most of the students were described to be highly motivated when working on the experiments and were surprised by some of the results, especially when they discovered that some of the pigments decompose upon heating. The inquiry-based nature of comparing different inks was also evaluated as a positive thing.

Feedback from the students

The positive feedback from the classroom observations agrees with the feedback recorded by the students. The pupils generally enjoyed the teaching unit and gave very positive feedback for both the open and Likert items in the questionnaire. A total of 65% of the students agreed or totally agreed that they enjoy chemistry learning more when it is embedded in issues like tattooing. Another 25% partially agreed. In the open questionnaire segment, students provided statements as: "*The lesson plan was great, because I learned many different things and the topic was very interesting*" and "*I liked the lesson plan during the last few hours. I enjoyed learning about so many different things concerning tattooing.*"

In the Likert questionnaire, similar responses answered the question as to whether or not learners prefer chemistry topics connected to societal issues: Here we found 65% agreement and total agreement and another 32% partial agreement to this statement. When asked if they liked the lessons because the issues were viewed as interesting for teenagers' everyday lives, the agreement was even higher with a total of 75% agreement or total agreement and another 22% of partial agreement. In the open questions many students made statements like: "*This lesson plan was relevant, because you think twice about getting a tattoo or not*" and "*The lesson plan was important for us [students], because many teenagers want to get a tattoo without thinking about the consequences.*"

Nearly 50% agreed or agreed totally that they have learned something that is meaningful for their personal life and 32% agreed partially. Statements about the teaching method were also positively acknowledged, including those made about the self-test pedagogy and the inquiry-based nature of the experiments: "*I enjoyed the teaching unit because we did a lot of experiments and investigations*" or "*I enjoyed the experiments, because I could better understand the content.*" More than 50% of the students agreed or agreed totally (another some 34% partially) that the lesson plan made them think more critically about tattooing. A further 40% agreed or totally agreed (another 40% partially) that they had started to think differently about the practice of tattooing. In the open questionnaire one student wrote: "*I am happy that I am not tattooed and now I never want to have one.*"

Motivational aspects of the lesson plan

The MoLE-questionnaire by Bolte (2006) investigated in a pre-post-design whether this type of teaching unit can contribute to increase students' motivation in chemistry lessons. A pre-questionnaire was used to collect student information on motivation in chemistry lessons prior to the teaching unit (real situation), including their wishes for an 'ideal' chemistry class (ideal situation). After the intervention on tattooing the learners gave feedback on their experiences during the lesson plan.

Although only 108 students provided feedback on the MoLE-questionnaire, many statistically significant aspects were able to be localised. Items 1 and 2 as presented in Fig. 5 reflect on the perception of relevance of chemistry education (dimension in the MoLE-questionnaire: subject relevance). In both items highly significant differences were found in the students' perception of previous chemistry lessons when compared to lessons the students would wish to have. Prior chemistry education was seen as less relevant than pupils wished for with

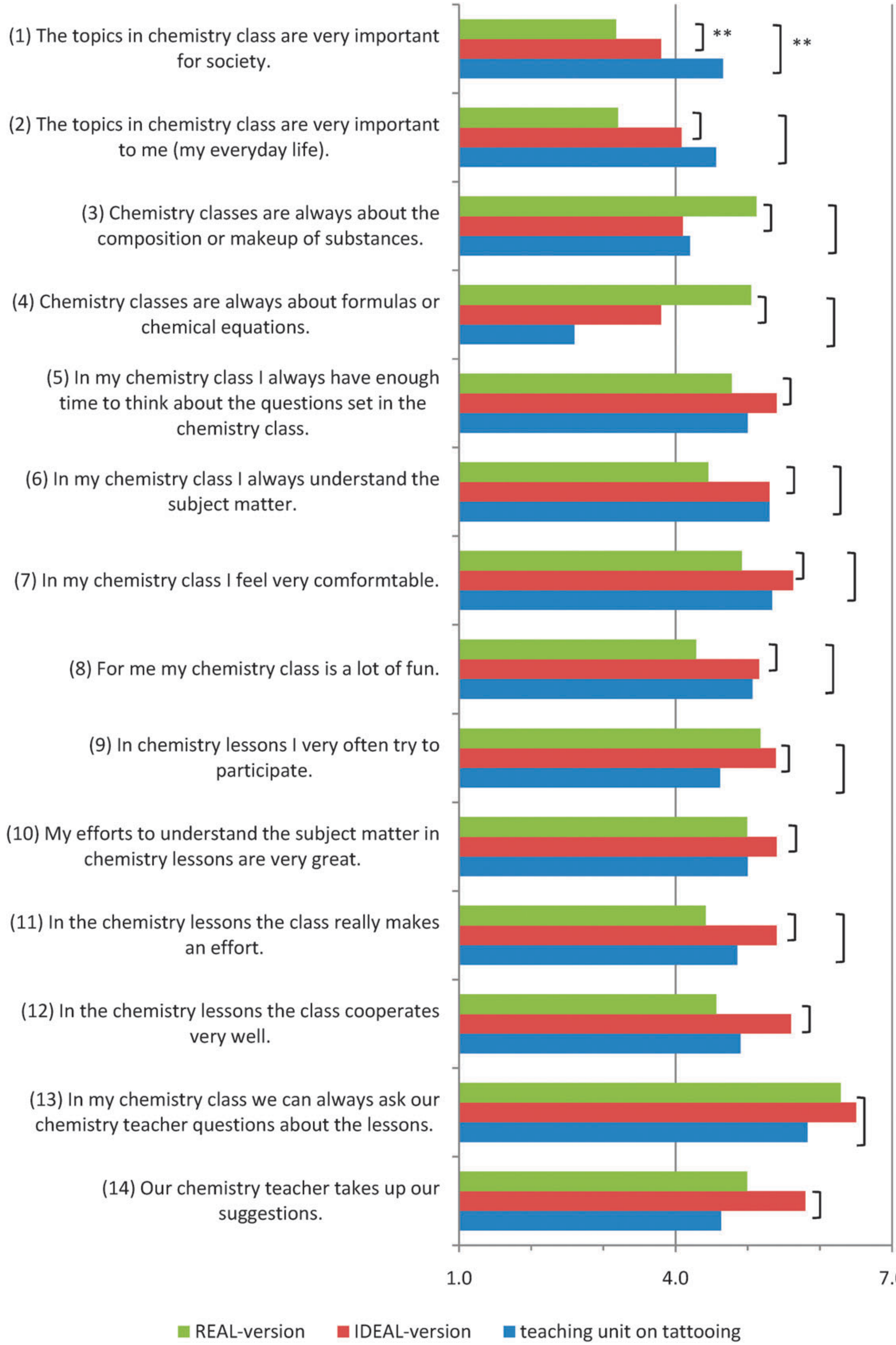

Fig. 5 Results of the MoLE questionnaire used for the teaching unit on tattooing (*: $p < 0.05$; **: $p < 0.01$).

respect to their lives and society. The tattooing lesson plan was perceived differently. There was a highly significant growth in the perception of relevance, even beyond the imagined 'ideal' situation. Items 3–6 reflect on the focus and understanding of chemistry classes (dimensions in the MoLE-questionnaire: subject orientation and comprehensibility). In all the four items there is a highly significant difference between the real and ideal situation. Students claim that their classes are generally too focused on the pure learning of chemistry content and that the chemistry lessons themselves are often hard to comprehend. The lesson plan on tattooing was viewed differently. There was a highly significant change in three out of the four items. In item 4 concerning the abstract nature of chemistry the change in perception went even beyond the ideal situation suggested by the students. These findings might also contribute to the feelings of comfort and fun. In items 7–8 (dimension in the MoLE questionnaire: satisfaction) the students suggested that they would like to be more comfortable and have fun in chemistry lessons. In both items there was a significant growth in the perception of satisfaction, thanks to the lesson plan on tattooing, which was near to the ideal situation presented by the participants.

This perception of satisfaction with the lesson plan was mainly caused by curricular change as compared to changes in pedagogy. Items 9–14 address aspects such as class cooperation, the amount of student effort, and student–teacher interactions (dimensions in the MoLE-questionnaire: willingness to participate, class cooperation, opportunities to participate). For most items the ideal situation was described as significantly different from the real classroom situation prior to the study. However, only a few aspects in this area changed significantly according to the students and the direction of change was not always towards the ideal situation as suggested by the students.

Discussion and implications

This paper describes a study on curriculum design based on Participatory Action Research (Eilks and Ralle, 2002). Its focus was on implementing curriculum change by employing a broadly student relevant topic as a driver for chemistry lesson change. Special emphasis was laid on carefully selecting the topic, which was based on a newly suggested framework by Stuckey *et al.* (2013) for reflecting on topics and their potential for creating more relevant chemistry education. This was carried out through a lesson plan for lower secondary school chemistry classes based on the chemistry of tattoo inks and the personal, societal and vocational issues involved in tattooing.

Student feedback on the lesson plan, taken together with the classroom observations and teacher feedback, revealed a highly-feasible and motivating lesson plan. Particularly the data from the MoLE instrument showed that the choice of this topic led to highly significant changes in the students' level of
Q6 motivation. This was mainly caused the perception of relevance of the topic.

Chemistry education is often viewed as unpopular by students. It is not perceived to be relevant or closely connected to the aspects of their everyday lives (Osborne and Dillon, 2008; Hofstein *et al.*, 2011). Results show that learners are generally described as insufficiently interested in science learning and/or unmotivated by science subjects (Osborne, 2003; Jenkins and Nelson, 2005). The current case reveals that carefully selected contexts, which are chosen with a thorough view of individual, societal and vocational relevance, might contribute towards overcoming these claims. The embodied framework (Stuckey *et al.*, 2013) offered guidance in the selection of and reflection on topics with respect to their potential in the chemistry classroom. The choice of tattooing as a subject proved itself to be highly motivating and viewed as highly relevant by the students. There are some indications that the theoretical underpinnings described in this paper for selecting relevant topics can aid teachers and curriculum designers to make more effective use of context-based and society-oriented science education. In terms of learner motivation and student perceptions of the relevance of science, the current case revealed that education in school has not achieved its utmost potential up to now.

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