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Raising students' perception of the relevance of science teaching and promoting communication and evaluation capabilities using authentic and controversial socio-scientific issues in the Framework of climate change

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Abstract
This paper describes the development of different lesson plans dealing with authentic and controversial socio-scientific issues in the framework of climate change. These lesson plans orient themselves along the socio-critical, problem-oriented approach to science teaching. They deal with the use of bioethanol as an alternative fuel and with the phenomenon of climate change itself. The development of these lesson plans for chemistry classes using Participatory Action Research will also be discussed. Parallel approaches to Physics, Biology and Politics education taken in the project "Climate Change Before the Court" will also be outlined briefly. Experiences from applying these lesson plans in German chemistry teaching are also discussed.

Key words: *student perception, relevance of science teaching, socio-scientific issues*

Introduction

One of the most general educational objectives is for pupils to learn about how socio-scientific issues are handled and evaluated within society to understand and to be able to act as a responsible citizen in future (e.g. Höttecke et al., 2010). Thus, a stronger societal orientation in science teaching remains a key demand for contemporary science education (e.g. Hofstein, Eilks & Bybee, 2010). It is also part of a larger debate about whether or not to orient science lessons more thoroughly in the direction of an education promoting sustainable development (De Haan, 2006). In more general terms, a stronger orientation is needed towards the philosophy of 'education through science' rather than 'science through education'. Such a direction change can help to re-orient science education in order to better fulfill the interests and needs of most students (e.g. Hofstein, Eilks & Bybee, 2010). In the words of Holbrook and Rannikmae (2007):

> *"... Science education should be regarded as, education through science 'rather than' education through science '. [...] This encompasses an understanding of the nature of science [education], with links to achievement of goals in the personal domain, stressing intellectual and communication skill development, as well as the promotion of character and positive attitudes, plus achievement of goals in the social education domain, stressing cooperative learning and socio-scientific decision-making. [...] The over-riding target for science teaching in school, as an aspect of relevant education, is seen in responsible citizenry, based on enhancing scientific and technological literacy."*

This debate is not new, stretching back for several decades. Nevertheless, it remains quite current. Questions still exist about orienting science education more thoroughly towards scientific literacy for all, what general educational objectives (*Allgemeinbildung*) should be, and how best to meet the needs and interests of all students (e.g. Hofstein & Yager, 1988). In more recent years these pleas have been repeatedly made by many scholars, political papers, and science initiatives. In order to fulfill the stated objectives, most of the papers presented urged educators to re-orient science lessons in the direction of more meaningful, authentic, relevant, and contextualized science education (e.g. Eilks, Marks & Feierabend, 2008; Gilbert, 2006; Hofstein & Kesner, 2006; Holbrook, 2005; Holbrook & Rannikmae, 2007). This was also mirrored by the widespread political debates in the wake of the ongoing TIMSS (since 1995) and PISA (since 2000; e.g. Bybee, Fensham & Laurie, 2009) studies. TIMSS and PISA sparked a tidal wave of documents calling for innovation in science teaching in the same direction the previous papers had demanded. Examples from around the world include the US report by John Glenn's committee entitled *'Before it is too late'* (2000). In Europe we find *Beyond 2000* (Millar & Osborne, 1998), the *Relevance of Science Education* study (Schreiner & Sjöberg, 2004), and *Science Education in Europe: Critical Reflections* (Osborne & Dillon, 2008). At the UNESCO level there is the rationale of *Project 2000+* (Holbrook, 1998; UNESCO, 1999). These reports all support the stronger orientation of science education programs toward the interests and needs of all students, including those who will never embark in a future career in science and technology. They call for strengthening the societal dimension of science teaching and also for fostering the recognition of general educational objectives in science teaching in order to help students become responsible future citizens.

Nevertheless, examples of such teaching approaches seem to be only rarely applied in a majority of countries (Hofstein, Eilks & Bybee, 2010). In Chemistry and Physics education, for example, an orientation on more general goals of education does not seem to be the driving force behind either curriculum planning or the daily practice of teaching. The main result of this is that science teaching remains unpopular among the students and is generally perceived as not being very relevant. This can be seen clearly for the physical sciences (Osborne, 2001; Holbrook & Rannikmae, 2007; Hofstein, Eilks & Bybee, 2010). These explanations prove to be very sound all over the world. Science teaching is still too strongly oriented along the inner systematics and content structure of the related academic disciplines. In other words, it remains content-driven. Science teaching still neglects the societal dimension of science teaching to a large degree, only rarely orients itself towards prescribed general educational objectives, and still basically ignores the interests of the vast majority of students who will never have careers in Chemistry or Physics (Bybee, 1987; Elmose & Roth, 2005; Holbrook & Rannikmae, 2007; Marks & Eilks, 2009; Hofstein, Eilks & Bybee, 2010).

Thus, there is broad agreement for change among educators. But exactly which topics and methods should then become the driving forces for future science education? Since the mid-1960s Klafki (2000) has promoted the idea of epoch-typical key issues ('epochaltypische Schlüsselprobleme') in the German-speaking parts of the world. He states that these should become the central tenets for any kind of education seeking to promote a responsible citizenry. The key issues are any topics which truly challenge a contemporary's society future. Klafki defined the questions of peace and of the environment as two key issues of his time. He believed that such key issues might provide the most promising textual approaches of teaching which actually fosters *Allgemeinbildung*. Klafki describes *Allgemeinbildung* (which can be translated by 'general education') as helping a person to raise his or her capabilities of self-determination, political participation, and solidarity with others within a democratic society (Klafki, 2000; see also e.g., Roth & Lee, 2004; Marks & Eilks, 2009; Hofstein, Eilks & Bybee, 2010). Also, Sadler (2004) describes respective challenges as the most fruitful settings for science education, but adds the aspect of their relatedness to contradictory viewpoints. He suggests choosing socio-scientific issues *"... which encourage personal connections between students and the issues discussed, explicitly address the value of justifying claims and expose the importance of attending to contradictory opinions*." In more detail, Eilks and Marks (2009) characterized a similar textual approach, stating that one of the most promising characteristics of such key issues are: 1) their authenticity, 2) their direct relevance to everyday life and 3) their openness to evaluation and societal debate, which allows for and encourages open discussion among the students (see below). They state that it is important that students recognize and understand that in such issues "*even the teacher does not have "the right solution". Such right solutions do not exist for this controversial kind of questions, and science only can help us to understand the background. Science offers the basis for evaluations. But, the evaluation has to be done by each person individually*" (Marks & Eilks, 2009).

In this sense, one of the most prominent epoch-typical key issues of our time is undoubtedly the question of climate change. Debates about climate change deal with a complex scientific phenomenon whose effects are not yet fully understood. Nor are any solutions unanimously agreed upon by society at large (Hulme, 2009). Aside from the scientific debate, climate change discussion employs questions on technology, policy, media, the economy, and other social aspects within a society. Additionally, differences between various societies around the world enter the picture. Climate change is a problem which calls not only for social consensus, but also individual action. In this context, it is essential for all democratic societies to have responsible citizens who can actively participate in the climate change debate and who understand enough to help make logical, well-reasoned decisions (e.g. Pettenger, 2007). Therefore, Bybee's (1997) multidimensional communication and evaluation capabilities are essential and should become the objectives of science teaching and possibly in other school subjects as well.

This is why the project "The Climate Change Before the Court" selected this issue, since it allows for the learning of science itself, while simultaneously using science teaching to promote general educational objectives. The project focuses on creating lesson plans for different domains of science teaching and includes special emphasis on contributing to learning how to behave and handle responsibly in society. Particular stress was placed on fostering students' communication and evaluation capabilities in the multidimensional sense outlined by Bybee (1997). Education for sustainable development was also highlighted, proceeding from De Haan's understanding (2006) that any socio-scientific issue must always be evaluated in a multidimensional fashion which incorporates its ecological, economical and social impacts.

The project 'The climate change before the court'

Objectives and method

'Climate Change Before the Court' uses interdisciplinary cooperation of educators from the fields of Chemistry, Biology, Physics and Politics education. Central objectives of the project are:

- Developing lesson plans to strengthen students' evaluation and communication capabilities in a multidimensional sense within the framework of climate change;
- Researching the feasibility and effects of the lesson plans; and
- Searching for domain-related cultures among teachers on how to deal with the interdisciplinary challenge of climate change within the different science teaching domains.

The method of development and research provides a joint framework for the work in all four subjects. The selected method was the Participatory Action Research (PAR) model for science education as presented by Eilks and Ralle (2002). In this design, teachers and researchers jointly develop and investigate teaching practices. Lesson plans are cooperatively designed, tested, researched and refined in a cyclical process. Thus, PAR directly combines the evidence of educational research with the practical experience of teachers. This effectively unites these two complementary resources and results in an overall improvement of teaching practices. A sketch of this model is given by Figure 1.

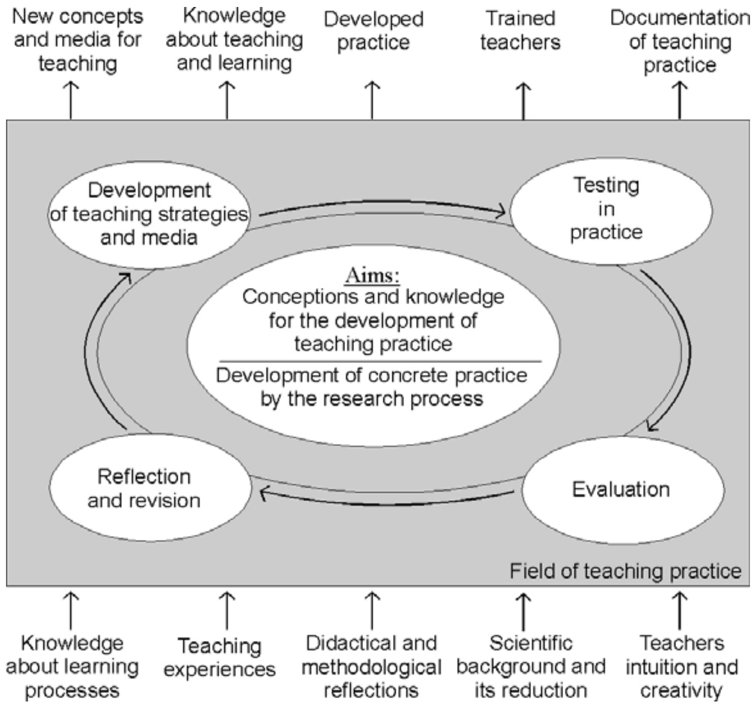

Figure 1: Participatory Action Research within chemical education (Eilks and Ralle, 2002).

In this particular project, one group of Participatory Action Research teachers ranging from 5-8 members was established for each of the four subjects mentioned above. The pilot study presented below was conducted using an already-existing Participatory Action Research group which has been working together now for 11 years (e.g. Eilks, 2007). The groups structured their lesson plans over a time period of about 1 year, working under the aegis of university science educators.

Didactical framework

Within the pilot study - and also in the four developmental projects - a joint framework was chosen for the planning of the lessons. All lessons were oriented along the socio-critical, problem-oriented approach to chemistry and science teaching, which was originally developed by Eilks (2000, 2002a), then refined into its present form by Marks and Eilks (2009). This approach organizes lesson plans using a five-step-model and begins by selecting a current, controversial socio-scientific issue being mirrored in authentic media, e.g. newspapers, magazines, or TV. The lesson plan incorporates a primary phase in which pupils learn the essential scientific material directly related to the problem. When the necessary foundational knowledge is mastered, the socio-scientific debate is resumed. The central phase teaching learners about both the societal dimensions of debates and the inherent interplay between science and society mimics authentic social practices. Possibilities include role-playing a talk show on TV (e.g. Marks, Bertram & Eilks, 2008), using the journalistic method (Marks & Eilks, 2010; Marks, Otten & Eilks, 2010), evaluating products just like a consumer protection agency would do (Burmeister & Eilks, 2010), or acting out the decision-making processes taking place within a parliamentary commission (see below). A model of the basic ideas of the socio-critical, problem-oriented approach to chemistry and science teaching can be seen in Figure 2.

Concept of the socio-critical and problem-oriented approach to chemistry teaching			
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 chemistry learning and lab-work	2. Clarifiying the chemistry background in a lab 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 chemistry and technology	Methods provoking the explication of individual opinions	5. Meta-reflection

Figure 2: Conceptual framework of the socio-critical, problem-oriented approach to chemistry teaching (Marks & Eilks, 2009).

A second joint feature was chosen for the project 'Climate Change Before the Court'. Each group was asked to structure phase 4 of the lesson (see above) using either a role-playing exercise or a business game. This forced learners to mimic societal or political decision-making processes while they were dealing with a controversial issue related to climate change. This particular approach was chosen to raise the learners' awareness of the societal dimension of climate change. It stresses the multi-dimensional character of such open debates by highlighting the dialogues taking place, the various options available for consideration and the different special interest groups which take part in the process. Peoples' (in)ability to deal with such competing opinions becomes evident and reveals the fact that societal problems often end in a dilemma. Two or more individual evaluations of a problem often are presented through contradictory argumentation. More importantly, such dilemmas can occur as an individual or a collective phenomenon (Hößle, 2007):

> *„Within individual dilemmas, the individual is asked for a decision, where her or his personal situation asks for a process of evaluation to lead to a decision for a specific personal action. On the other hand, collective dilemmas are characterized by a high degree of societal relevance and potential actions which only can be executed as a collective. Strategies of avoidance and conformation in the context of climate change are a good example. Competitive and cooperative structures of action are in a permanent conflict (Shall I reduce my CO_2 emissions by not using the*

> *car? This only would make sense, if all others will do the same!).”* (Eilks et al., 2010)

The role-playing/business game approach was consciously chosen by the lesson planners in order to make such dilemmas explicitly clear to the learners. They showed that experimental games also have a role to play in science education. The various forms proved very suitable for examining conflicting societal interests and also for promoting and evaluating learning. The exercises transformed the classroom itself into a company, a newspaper, a governmental body, a consumer protection agency or a TV talk show, thereby allowing students direct access to the very social structures and processes that they were supposed to analyze and criticize (Yardley-Matwiejczuk, 1997). Furthermore, role-playing represents an excellent tool for working on learners' communication skills. Pupils cannot make exclusive use of colloquial language. They are forced to employ more formal language and subject-specific jargon, so that they develop and practice communication skills which allow them to function in nearly every societal situation (Porter Ladousse, 1987)

Testing and evaluation

A cyclical program of development, testing, analysis and refinement was carried out, including repeated testing of the pilot lesson in chemistry and the different climate change modules for all four subjects. Accompanying teacher feedback was monitored by videotaping the action research group meetings. Student feedback was collected using feedback questionnaires which contained both open and Likert items. Additionally, student performance was monitored by videotaping central parts of the lessons and through the use of pre- and post-learning group discussions. In the pilot study, only teacher feedback and the student questionnaires were used for evaluation.
All of the test instruments focused upon lesson plan feasibility, students' viewpoints concerning climate change and learner self-reflection on the decision-making process within the lesson plan. All data underwent qualitative evaluation, e.g. by qualitative content analysis (Mayring, 2002).
This paper deals primarily with the feasibility of the chemistry lesson plans in the pilot and main study. Insights gained will be presented and discussed here, and a short outlook on the other data will be given.

A pilot study on the use of bioethanol as an alternative fuel

Starting points

A pilot study on bioethanol as an alternative fuel source (Feierabend & Eilks, 2010) was conducted to test the feasibility of the main teaching methods selected for the climate change developmental process. This topic was chosen because of previous experience and promising results from a biodiesel lesson plan developed about 10 years ago, which used a related framework (Eilks, 2000, 2002a). This lesson was based on the need to reduce carbon dioxide emissions and deals specifically with the use of renewable energy sources for the production of fuels. The controversial character of this issue arises from using corn and other agricultural food products as a source for fuel, which might decrease overall available food stocks and/or cause skyrocketing food prices in some countries.

The lesson plan

The teaching module was designed for grades 10-11 (age range 15-17) in German secondary grammar schools. Depending on the different syllabuses in German-speaking countries, the lessons can either be used as an introduction to the chemistry of organic compounds as such, or as a unit on the chemistry of alcohols.

A textual approach was chosen based on an authentic 2007 article from political magazine DER SPIEGEL, which published a special issue on renewable energy sources. The article dealt with the pros and cons of bioethanol use, specifically addressing the competition between food and energy producers (Brown, 2007). The paper explicitly showed that the use of corn to produce bioethanol is highly controversial in society. In the US, for example, a debate still rages over rising corn prices in Mexico. The US not only uses its own corn production to manufacture bioethanol, but also buys additional, large quantities of corn from the world market, which are no longer available to other nations for food. The discussion in the lesson about the article is meant to provoke questions incorporating multiple facets, e.g. the chemical, technical, socio-economic and ethical dimensions of the issue. Similar materials for this topic can easily be found on the Internet in nearly every language of the world.

Some basic scientific and technological content is taught to allow learners to better understand the subsequent debate and following evaluation. This is carried out using a related method to that in the biodiesel example (Eilks, 2001, 2002a), which includes conducting experiments and theoretical tasks in a learning at stations mode (Eilks, 2002b). As an additional feature, the learning of theory and labwork is embedded into a jigsaw classroom (Figure 3) in order to better connect theory and hands-on experience.

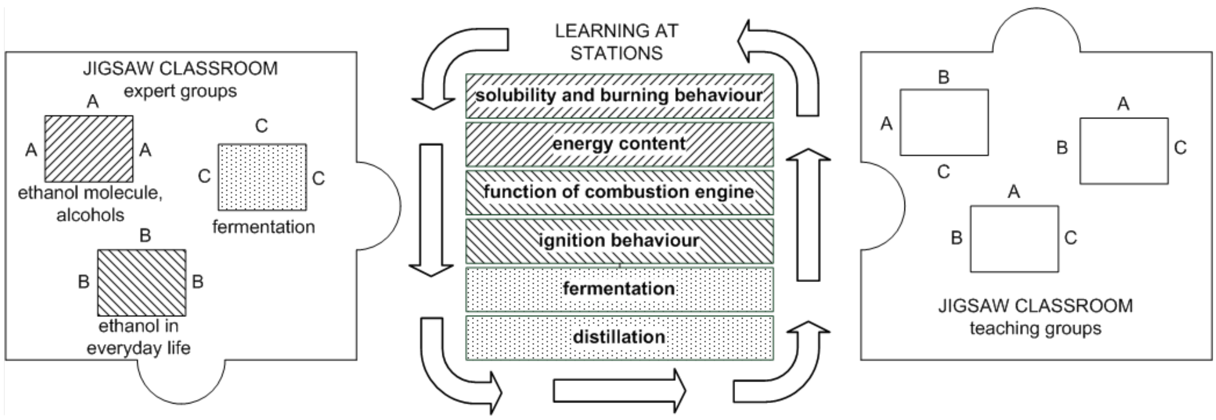

Figure 3. Learning the basic science background through a combination of a learning-at-stations lab and a jigsaw classroom

This phase of teaching starts with an initial round of the jigsaw classroom, similar to the one described in Eilks and Leerhoff (2001). The students in the first round form two groups each for three topics (six groups total): the structures of the ethanol molecule and the alcohol family, the production of ethanol by alcoholic fermentation and distillation, and the occurrence of ethanol in everyday life. The jigsaw classroom, however, does not reorganize into the expert teaching round as it normally would do. Instead, the expert groups move on to the learning-at-stations lab phase. This environment offers learners six different experiments (Figure 3). Each group is only capable of completely conducting and evaluating two of the six stations, based on their previous learning experiences in the expert group phase. The remaining four experiments are first conducted without solving all of the evaluations tasks. In the following jigsaw classroom phase (the expert round), each expert now presents the two areas in which he/she is fully competent. Members of the group spread comprehension by effectively explaining two of the four experiments which the other experts could not completely understand. At the same time, they receive the same kind of help in their own weak areas by listening to the other experts. The end effect is that all members gain expertise in each of the six areas by the end of the expert round. They now can completely analyze all of the remaining evaluation tasks for the other four stations by themselves. Structure and help for this phase is given by providing ten questions (one about each experts' subject, one for each of the six learning stations, and one requiring a transfer of knowledge to a new topic).

The second part of the lesson plan resumes the socio-scientific debate. Reflection occurs about which of the initial questions had been answered purely on the basis of content-based learning – and which ones had not! Even after the factors concerning scientific background and content knowledge have more or less been made clear to the learners, an evaluation of bioethanol use based on its ecological, economical and social impacts remains a wide-open question. At this point, a business game is introduced to allow students insights into the societal debate. They are confronted with the fact that easy solutions, consensus-making and hard-and-fast decisions are usually in short supply in a democratic society. The business game in this instance mimics the decision-making processes taking place in parliamentary committees. The core idea is to give stakeholders an equal and fair chance to express their particular position on the issue. For added motivation, a scenario involving a fictitious constitutional act is introduced. In this instance, this bill states that in the future at least 30% of all conventional car fuels will have to consist of bioethanol. Whatever the decision of the committee, it will become a law binding all of the German people. This scenario is very authentic because only a few years ago the German government intended to pass just such a law, albeit with a lower percentage of bioethanol. The law was never implemented due to pressure from the motor vehicle industry and its special interest lobby groups.

In real life, such a draft bill would first be discussed in a parliamentary committee, in Germany's case the Committee for Research and Technology Assessment. Parliament would then make a decision, based on the committee's final recommendation. The committee informs itself by listening to experts, whose arguments mirror the different interests, stakeholders and pressure groups in society. The committee's job is to assess and prioritize the strengths and weaknesses of the different points-of-view and then use this information to formulate a decision. In the lesson plan, the students form different expert groups based on various potential stakeholders in society. They prepare themselves for the parliamentary hearing by using materials provided to them from various sources, including the Internet, industrial publications, etc. The perspectives chosen for this teaching unit consist of: technology, agriculture, developmental policy, and economy. Each group of learners receives two sheets filled with basic information, including details that are technical in nature, and is given a position on the topic to defend. In addition, Internet addresses with further information are provided. During the selection of learner resources, it is important to find compact web pages which do not bury the students under an avalanche of information. Nevertheless, the groups should be allowed to add information that they found themselves, since learning how to select relevant information is also a goal of the lesson. Specifically, pupils need to learn 1) to separate important points from unimportant trivia and 2) to assess the reliability and the ulterior motives of a given source. Now that they have a specific task to carry out, the experts can now benefit from the knowledge they gained in the content learning phase. For example, the technology experts can put their knowledge about how combustion engines function to good use in formulating their arguments. The agricultural experts can show the opportunities and risks of an increase in cereal production like the danger of monocultures or that of erosion. The developmental experts must include the impact of bioethanol technology on main producers such as Brazil, defining the ecological and social risks. The experts on economic issues need to consider the effects on the local economy and summarize the potential of bioethanol production within the EU. A fifth group of students serves as the parliamentary committee. This group receives a different kind of information. The committee does not acquaint itself with the facts per se, but is provided with an overview of the various experts and their potential interests. This background information must be used in order to pinpoint specific problem areas and to formulate concise and critical lines of questioning.

During the hearing, all groups are given exactly three minutes to present their arguments. They are given another three minutes to answer follow-up questions from the committee's members. Experts must decide which of their arguments they wish to present and in what order of significance. On the other hand, the committee members are forced to coordinate their examination with one other and to carefully consider which questions to ask the experts. Time management therefore becomes crucial on both sides of the table. At the end of the hearing, the committee has to formulate an official decision and to justify it in front of the entire audience. Here, the question of which decision was drawn is much less important than the group reflection on the reasons and justifications behind the committee's conclusion. This includes how the experts behaved under examination and how this may have influenced the final decisions. The fact that there even is a decision in this case will not necessarily guarantee that it is a clear one, nor will everyone agree with the committee's rationale and finding. Even with a so-called "official" consensus the debate will not end for the participants, thus providing the possibility that the learners take the discussion outside of the classroom.

Experiences and results

This lesson plan was developed within a Participatory Action Research project (Eilks & Ralle, 2002) by a group of teachers in a western German city. The lesson has been tested in several optimization cycles using various 10th and 11th grade classes (age range 16-17) in different grammar schools. The unit lasts a total of about 7-10 hours (45 min. classroom periods).

The teachers reported that the lesson was well received by students, who showed high levels of interest and motivation. This was primarily tied to the intensity and quality of the ensuing discussions. The teachers emphasized the fact that both the previously-learned science content and the information from outside sources were repeatedly drawn into the discussion. It was pointed out that this scenario went far beyond a discussion to end in a "binding" decision. This made it clear that educators need to deal with dilemmas both on the individual and on the collective level.

The students also gave consistently positive feedback. One of the open questions in the questionnaires aimed specifically at learner assessment of chemical education. Again and again, the students referred to notions like "interesting," "informative" and "fun". Many students classified the approach as good or interesting. The possibility of independent work and group learning was quite often mentioned positively. In some student responses, however, uncertainties emerged: "..., I do not know whether that belongs in chemistry class, " or "..., it differs in content from normal chemistry class, which means that a lot of knowledge touches on other, different domains." Rather unintentionally, these students identified the necessary interdisciplinary approach and multiple perspectives of the issue when they tried to give a multidimensional evaluation.

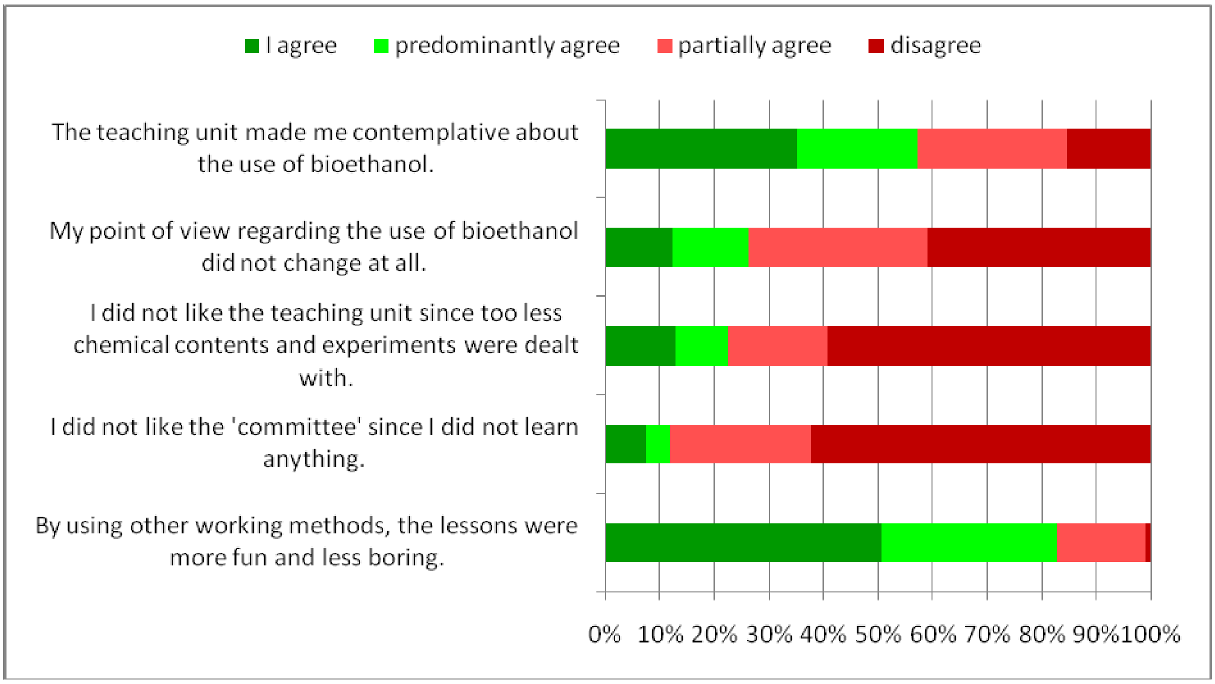

Figure 4: Excerpt from the Likert questionnaire

The items on the Likert questionnaire supported the statements made by pupils to the open questions (Fig. 4). Particularly positive assessment was assigned to the joint work phase due to the cooperative learning methods. In this area, almost all students agreed - at least partially - that they enjoyed the series of lessons, since the knowledge been worked out together with their classmates. Fifty percent of the students agreed completely with this statement. The same was stated for an item expressing the idea that the use of other methods makes science lessons more fun and less boring. Even though some students said it was rather strange to have a discussion phase and role-playing exercise in the chemistry class (open questionnaire), only 10% of the Likert answers professed a dislike of the business game, allegedly because they felt that they had learned nothing during this phase. However, 65% of the students did not express this feeling at all and denied this assessment completely. About 95% of students at least partially agreed that the lessons contained specific content that they had a personal interest in. Half of the students agreed with this statement completely and the majority of the rest "mostly agreed". Slightly under 90% of students agreed - at least in part - that they had been made thoughtful about the use of bioethanol by the series of lessons. Almost 90% more-or-less agreed with the statement that they would now evaluate bioethanol differently than they would have before the series of lessons took place.

A chemistry lesson plan on climate change

Starting point

Based on the experience of the bioethanol lesson plan, the main phase of this project developed similar lesson plans more clearly focusing on the topic of climate change. This was carried for all four subjects by another group of teachers in northern Germany, using the same theoretical resources and the development model. The chemistry group focused on the behavior of carbon dioxide and contrasted different kinds of fuel (conventional vs. renewable). The group developed a lesson plan of about 10 periods (each 45 min.) for a 9th grade target group (age range 15-16). In this case, lesson plan development and evaluation mainly took place in middle and comprehensive school classes.

The lesson plan

The lessons begin with a film excerpt called 'Looking on global warming favorably', a political satire from television which had been posted on Youtube. In this video, facts about climate change and its consequences are distorted, exaggerated and used in very ironic fashion: "Who wouldn't welcome warmer summers and palm-fringed beaches on Germany's North Sea coast?" This media clip was selected to provoke a preliminary discussion and pinpoint the students' level of knowledge about climate change, its causes and the potential consequences.

With a view of the business game phase, the teachers are asked to pre-divid the learners into their expert roles right from the start. The six roles selected were: the committee, experts in climate protection, mobility and transport, green mobility, climate research, and the automobile industry. The provocative scenario in this case is a bill proposing to raise the legal driving age back up to 21 to reduce the number of potential drivers and thereby the emissions of carbon dioxide.

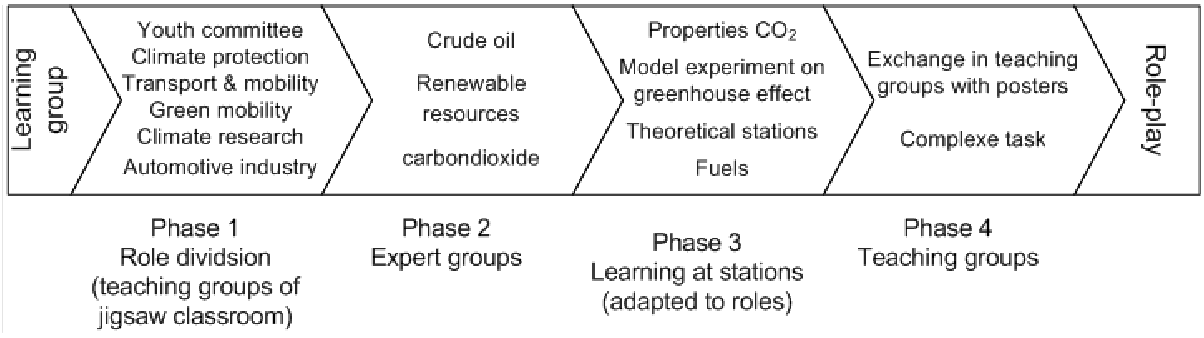

Figure 5: Survey of the jigsaw learning-at-stations-classroom in the Chemistry lesson plan

As in the pilot study, a jigsaw classroom is used to teach science content. The topics for the expert groups in the jigsaw classroom are: carbon dioxide, renewable sources of energy, and crude oil production/technology. The students create posters in the expert groups to consolidate their knowledge into useful forms for the teaching rounds later in the jigsaw classroom. In between, again a learning-at stations labwork has to be conducted with a total of eight stations. The students don't have to conduct all stations in this version. Each expert group receives information about which of the stations are mandatory and which are optional (Fig. 5). The stations offer an open lab setup where students can pick and choose experiments according to their assigned roles in the business game. Nevertheless, they are given advice as to which of the stations might prove the most useful for each of the expert topics. During the teaching round of the jigsaw classroom, students exchange information on the other experts' knowledge and activities in the learning at stations lab. Then the students prepare themselves for their committee roles with the help of prepared worksheets and additional Internet resources.

In the business game, the experts present their arguments to the committee one after the other with the same time limits and question-and-answer period. At the end of the hearing, the committee again makes its decision and justifies it in front of the entire class. During the reflection phase essential aspects of the decision-making process and the role-playing are discussed. This phase is often seen to be as important as the activity phase itself (Porter Ladousse, 1987). Otherwise, the students will remain unsatisfied with the roles they have played.

Experiences

The observations from the classroom were quite similar to those described above in the bioethanol unit. During the developmental stage, four teachers taught the lesson plan to a total of seven classes from different middle and comprehensive schools. This compassed students who on average were lower achievers than in the bioethanol case study, where the students were older and from the higher level of grammar school.

The question did arise whether such a satiric entry into the subject was appropriate for these lower achieving students. In the case of two classes, the students were not fully able to recognize the intended irony in the cartoon. Thus, in later testing a more concrete, non-ironic introduction was chosen, like the one selected in the bioethanol example above. Another factor was that the driver's license dilemma was not equally accepted in all schools. It quickly became clear that this depended upon the geographical location of the school. Students living in the city said that it would be no problem for them to simply use public transportation, but pupils living in the countryside desire a driving license as early as possible so that they are no longer dependent on their parents. Therefore, a second, urban scenario was also developed in which a school committee must decide whether school trips by plane should be forbidden up to 10th grade. This seemed to be a bit more provocative for students living in the city center, especially since they tend to be accustomed to good public transport facilities.

Nevertheless, even this lesson plan was considered to be a valuable enrichment of the chemistry curriculum (see below). This was especially true where two of the seven classes conducted the learning at stations labwork as a block course in a university

lab. The ability to work coherently in an out-of-school location contributed to better learning integration and focus.

In the questionnaire the students were asked about the lesson plan itself and their perceptions of it. Just as in the pilot study, this unit made the students think more about climate change, with nearly 70% of the students at least predominantly agreeing with such a statement (Fig. 6).

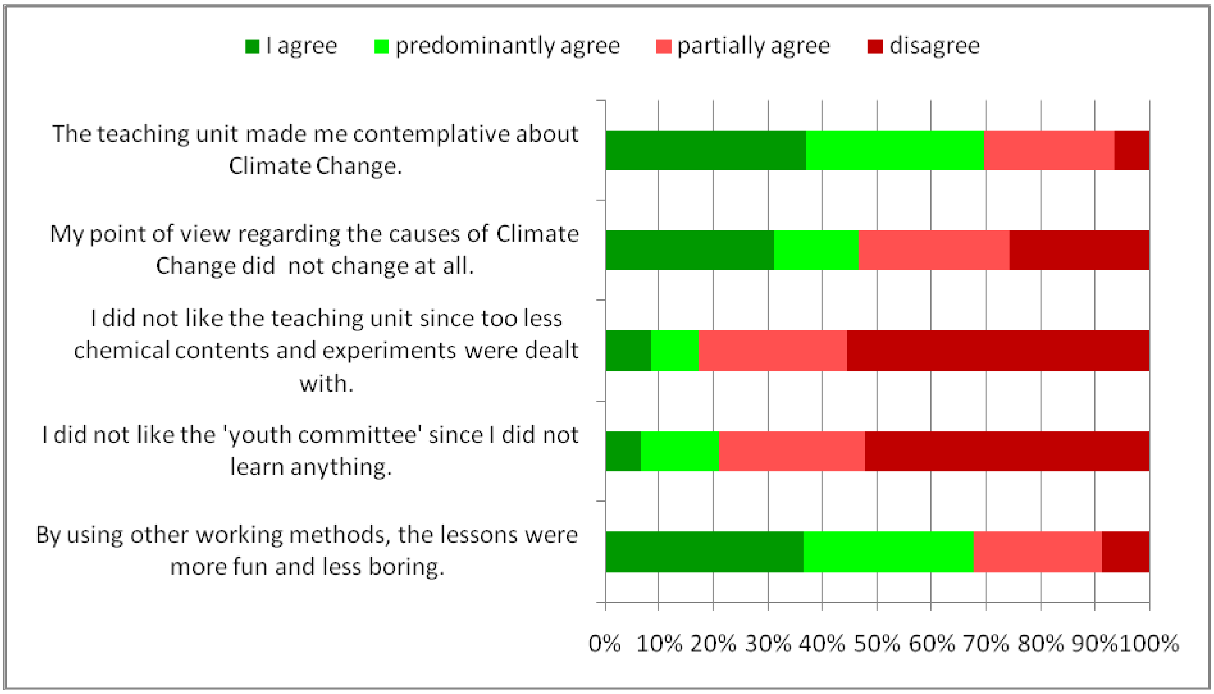

Figure 6: Excerpt from the Likert questionnaire

Once again it became obvious that students like the fact that there is more than pure chemistry in the unit. Furthermore, the students liked the business game element as part of chemistry teaching. In both cases the total agreement was above 50%. In addition, nearly 70% of the participants predominantly agreed that they enjoyed the lesson plan because it dealt with content which personally interested them. Again nearly 70% of the pupils agreed that they liked the lesson plan's methods, because they were able to work out things together with their classmates.

We also asked the students three supplemental open questions in addition to the Likert items. The first question asked what the students held to be the most important things they learned during the lesson plan. Here, over 60% of the students concentrated their replies on the content knowledge („I learned a lot about climate change in general, i.e. about the reasons for climate change and ist effects.“). Only 13% mentioned social skills („… that we learned to argue on one topic from different perspectives.”) and another 16% said that they had learned both. These younger students from middle and comprehensive schools did not seem not be so self-reflective about the educational approach when compared to another group described in a similar study by Eilks (2002). In this other study, nearly all of the students had recognized the general educational objectives behind such an approach.

The second open question asked the students for an assessment of the lesson plan. An overwhelming majority of over 70% gave positive feedback with a specific focus on the teaching manuals as a positive element („We learned a lot of information and by doing the experiments we learned more details about climate protection, climate change, etc. and we could show our knowledge/the learned content in the expert groups an the role play.“). This aspect was also the most-mentioned factor in the few negative feedback answers given by 14% of the students.

Finally, the third question asked participants to give a reasonable valuation of whether climate change can be stopped and what they personally could do to achieve it. A lot of the students believed that climate change still can be stopped („Yes,l it can be stopped. Politicians can make laws, e.g., on one day a month not to use cars, because this would reduce the emission of greenhouse effect gases.“). The rest of the students is divided into those who think that it is already too late and those who say that it can only be slowed down („This is funny … On the one side I’m interested in climate change, on the other side I don’t care. I could turn off the light, this is what I normally would have answered. But, I scarcely do have a serious idea. Climate change is already too distinctive to be stopped as we experienced this year’s spring.“).

Looking at the results of the group discussions, first trends in the present state of data analysis can be recognized. In the discussions, we confronted the students among other things with two dilemmas: 1) a school in a German city where students are forbidden to come to school by car (pre-discussion group) and 2) an EU-wide ban on conventional lightbulbs demanding immediate replacement by energy-saving lamps (post-discussion group). The students were asked to list possible pros and cons, who the decision-makers might be and what their own ideas of how such decisions should be made looked like. In the first step the learners' arguments were grouped together based on their content.

It was readily observable that in the pre-discussion dilemma, most of the pros and cons named by the students came from their personal background and focused on being a good example for others. The pupils had a wide variety of ideas concerning the decision-makers, where such decisions are made and who is in charge of them. These ranged from the headmaster all the way up to federal politicians like the Minister of the Environment. When asked for the best way to reach a decision, the participants preferred a democratically-based procedure which included all groups within school life. One student remarked: „Students, teachers and parents should decide together, because this would be the most democratic option."

In the post-discussion groups, the students viewed the pros of a conventional lightbulb ban primarily in economic and ecological terms as is illustrated in the following quotation: „They save energy, because 95% of the energy in conventional light bulbs is transformed into heat; this is not the case for the low energy bulbs." The cons were dominated by personal reasons, which were mainly connected to convenience. Here students said, for example: „They are expensive." or „The light is so ugly." The post-discussion groups also chose a different path for the decision-making procedure. Students preferred that EU politicians decide the matter for them, since some of them believed that such a decision would otherwise never be realized. But, this data still needs to be evaluated more deeply.

Overall, this unit also managed to generate high levels of motivation and to stimulate intense discussions. Once again, some of the students were unsure whether this kind of teaching and the aspects of societal decision-making really belonged in chemistry lessons. But, this might be more a questioning of the conventional topics and practices chosen for chemistry teaching than any consideration of the chosen approach itself. Chemistry without a doubt is one of the central disciplines dealing with questions of sustainable development and other related factors. Nevertheless, to students in school it seems to remain a pure academic construct. It is not understood, or not even taught, that chemistry itself includes its own role and interaction with society and future societal development. So perhaps the impression of chemistry given to students in previous lessons had given a wrong-headed idea about what actually belongs in chemistry, especially when the subject is presented as being more than just a conglomeration of facts and theories (see e.g. Marks & Eilks, 2009; 2010).

Outlook

In parallel to the chemistry lesson plan, units were also developed for physics, biology and politics classes. The framework of the units remained the same in all cases. The lesson plans aimed at developing multidimensional capabilities for communication and evaluation. All of the lesson plans were structured using the socio-critical, problem-oriented approach described above, including the use of role-playing and business games for mimicking societal debate on climate change. Despite these similarities, the respective teachers selected different subject-specific foci and content (see Table 1). Nevertheless, the classroom experiences evidenced many parallels to those reported in the above examples and proved that the chosen approach is also applicable within the other school subjects.

Table 1. Overview of the lesson plans from the various projects (Höttecke et al. 2010)

	Textual approach	Science content	Role-playing scenario
Biology	Authentic magazine cover and article	e.g. the relationship of food production and the emission of greenhouse gases	A school's decision not to offer meat dishes in the school restaurant
Chemistry	Satirical Youtube video on the effects of climate change	e.g. use of conventional and renewable fuels for cars and their comparison	Raising the minimum driving licence age to 21 years old
Physics	Scientific presentation on climate change and its potential effects	e.g. heat absorption by gases and the radiation budget of the earth	Stopping the import of fruits brought to Europe by air transportation
Politics	TV report on the competition between food and fuel production		Establishing a new law for the compulsory admixing of bioethanol and conventional fuels

Just as in other studies using this teaching approach (e.g. Marks & Eilks, 2009), it appears that the lesson plans developed for the topic of climate change are very feasible and motivating, thanks to the process of cyclical development. There are many indications that mimicking societal debates has the potential to provoke self-reflection on the handling of socio-scientific issues within society. We were also able to recognize indications that learners' perception of the relevance of science teaching rose in the students' estimation for all four subjects. Also in the case of climate change, this seems to show that the socio-critical, problem-oriented approach to teaching allows for innovation in science classrooms and leads to higher levels of motivation and a greater perception of the relevance of science for everyday life.

References

Brown, L. (2007). Sprit für die Welt. www.spiegel.de/spiegelspecial/0,1518,474490,00.html (20.08.10).

Burmeister, M., & Eilks, I. (2010). *Evaluating plastics: Education for sustainable development in chemistry teaching.* In J. Holbrook, M. Rannikmae, R. Soobard, B.Cavas & M. Kim (eds.), *Innovation in science and technology education: research, policy, practice* (3rd World conference on science and technology education) (pp. 239-242), Tartu: University of Tartu.

Bybee, R. W. (1987). Science education and the science-technology-society (STS) theme. *Science Education,* 71(5)*,* 667-683.

Bybee, R. W. (1997). Toward an understanding of scientific literacy. In W. Gräber & C. Bolte (eds.), *Scientific literacy – an international symposium* (pp. 37-68). Kiel: IPN.

Bybee, R., Fensham, P. J., Laurie, R. (2009). Special Issue: Scientific Literacy and Contexts in PISA Science. *Journal of Research in Science Teaching*, 46 (8), 861-960.

De Haan, G. (2006). The BLK '21' programme in Germany: a'Gestaltungskompetenz'-based model for Education for Sustainable Development. *Environmental Education Research*. 12(1), 19-32.

Eilks, I. (2000). Promoting scientific and technological literacy: teaching biodiesel. *Science Education International,* 11(1), 16-21.

Eilks, I. (2002a). Teaching 'Biodiesel': A sociocritical and problem-oriented approach to chemistry teaching, and students' first views on it. *Chemical Education: Research and Practice in Europe,* 3(1), 67-75.

Eilks, I. (2002b). "Learning at Stations" in secondary level chemistry lessons. *Science Education International* 13(1), 11-18.

Eilks, I. (2007). From Technical to Emancipatory Action Research – A six year case study on science teachers involved in a cooperative curriculum development project. Paper presented at the 6th Conference of the *European Science Education Research Association,* Malmoe, Sweden, 21 August – 25 August 2007, CD-ROM.

Eilks, I., Feierabend, T., Höttecke, D., Hößle, C., Menthe, J., Mrochen, M., & Oelgeklaus, H. (2010). Bewerten Lernen und Klimawandel in vier Fächern – Erste Einblicke in das Projekt „Der Klimawandel vor Gericht" (Teil 1 und 2). *Der Mathematische und Naturwissenschaftliche Unterricht,* accepted for publication.

Eilks, I.,& Leerhoff, G. (2001). A jigsaw classroom - Illustrated by the teaching of atomic structure. *Science Education International, 12* (3), 15-20.

Eilks, I., Marks, R., & Feierabend, T. (2008). Science education research to prepare future citizens – Chemistry learning in a socio-critical and problem-oriented approach. In B. Ralle & I. Eilks (eds.), *Promoting successful science learning – The worth of science education research* (S. 75-86). Aachen: Shaker.

Eilks, I., & Ralle, B. (2002). Participatory Action Research in chemical education. In B. Ralle & I. Eilks (eds.), *Research in chemical education - what does this mean?* (pp. 87-98). Aachen: Shaker.

Elmose, S., & Roth, W.-M. (2005). Allgemeinbildung: Readiness for living in a risk society. *Journal of Curriculum Studies*, 37(1), 11-34.

Feierabend, T., & Eilks, I. (2010). Learning chemistry and mimicking political decision-making processes – a participatory action research study evaluating a lesson plan on bioethanol as a fuel. In M. F. Taşar & G. Çakmakcı (Eds.), *Contemporary science education research: Scientific Literacy and social aspects of science* (pp. 123-130). Ankara, Turkey: Pegem Akademi.

Gilbert, J. K. (2006). On the nature of context in chemical *education*. *International Journal of Science*. *Education*, 28(9), 957-976.

Glenn, J. (2000). *Before it's too late: a report to the nation from the national commission on mathematics and science teaching for the 21st century*. Washington.

Hofstein, A., Eilks, I., & Bybee, R. (2010). Societal issues and their importance for relevant science education. In I. Eilks & B. Ralle (eds.), *Contemporary science education* (pp. 5-22), Aachen: Shaker.

Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: making chemistry studies more relevant. *International Journal of Science Education*, *28* (9), 1017-1039.

Hofstein, A., & Yager, R. E. (1986). Features of a quality curriculum for school science. *Journal of Curriculum Studies*, *18*(2), 133-146.

Holbrook, J. (1998). Operationalising scientific and technological literacy – a new approach to science teaching. *Science Education International*, *9*(2), 13-18.

Holbrook, J. (2005). Making chemistry teaching relevant. *Chemical Education International*, 6 (1), retrieved August 01, 2009, from the World Wide Web at http://old.iupac.org/publications/cei/vol6/06_Holbrook.pdf.

Holbrook, J., & Rannikmae, M. (2007). The nature of science education for enhancing scientific literacy. *International Journal of Science Education*, 29(11), 1347-1362.

Hößle, C. (2007). Theorien zur Entwicklung und Förderung moralischer Urteilsfähigkeit. In D. Krüger & H. Vogt (eds.), *Handbuch der Theorien in der biologiedidaktischen Forschung*. (pp. 196-207), Berlin: Springer.

Höttecke, D., Hössle, C., Eilks, I., Menthe, J., Mrochen, M., Oelgeklaus, H., & Feierabend, T. (2010). Judgment and decision-making about socio-scientific issues: A fundament for a cross-faculty approach towards learning about climate change. In I. Eilks & B. Ralle (eds.), *Contemporary science education* (pp. 179-192), Aachen: Shaker.

Hulme, M. (2009). *Why we disagree about climate change. Understanding controversy, inaction and opportunity*. Cambridge: Cambridge University Press.

Klafki, W. (2000). The significance of classical theories of Bildung for a contemporary concept of Allgemeinbildung. In I. Westbury, S. Hopmann & K. Riquarts (eds.), *Teaching as a reflective practice: the German Didaktik tradition* (pp. 85-108). Mahwah: Lawrence Erlbaum.

Marks, R., Bertram, S., & Eilks, I. (2008). Learning chemistry and beyond with a lesson plan on potato crisps, which follows a socio-critical and problem-oriented approach to chemistry lessons – a case study. *Chemistry Education: Research and Practice,* 9(3), 267-276.

Marks, R., & Eilks, I. (2009). Promoting Scientific Literacy using a socio-critical and problem-oriented approach in chemistry education: concept, examples, experiences. *International Journal of Environmental and Science Education,* 4(3), 231-245.

Marks, R., & Eilks, I. (2010). The development of a chemistry lesson plan on shower gels and musk fragrances following a socio-critical and problem-oriented approach – A project of Participatory Action Research. *Chemistry Education: Research and Practice,* 11(2) 129-141.

Marks, R., Otten, J., & Eilks, I. (2010). Writing news spots about chemistry – A way to promote students' competencies in communication and evaluation. *School Science Review* accepted for publication.

Mayring, P. (2002). Qualitative content analysis - research instrument or mode of interpretation? In M. Kiegelmann (Ed.). *The role of the researcher in qualitative psychology.* (pp. 139-148), Tübingen: Verlag Ingeborg Huber.

Millar, R. & Osborne, J. F. (eds.) (1998). *Beyond 2000: Science Education for the Future*. London: King's College.

OECD. Deutsches PISA Konsortium (2000). *Schülerleistungen im internationalen Vergleich. Eine Rahmenkonzeption für die Erfassung von Wissen und Fähigkeiten*. Berlin. MPI.

Osborne J. F. (2001). Science education for contemporary society: problems, issues and dilemmas. In O. de Jong, E. R. Savelsbergh, & A. Alblas (eds.), *Teaching for scientific literacy* (pp. 15-26). Utrecht: cdB.

Osborne, J., & Dillon, J. (2008). *Science education in Europe: critical reflections.* London: Nuffield Foundation.

Pettenger, M.E. (2007). *The social construction of climate change*. Farnham: Ashgate.
Porter Ladousse, G. (1987). *Role play*. Oxford: Oxford University Press.

Roth, W. M., & Lee, S. (2004). Science education as/for participation in the community. *Science Education*, 88(2), 263-291.

Sadler, T. D. (2004). Informal reasoning regarding socioscientific issues: A critical review of research. *Journal of Research in Science Teaching*, 41(5), 513–536.

Schreiner, C., & Sjøberg, S. (2004). *Sowing the seeds of ROSE. Background, rationale, questionnaire development and data collection for ROSE (The Relevance of Science Education) - a comparative study of students' views of science and science education.* Acta Didactica 4/2004. Oslo: University of Oslo.

UNESCO (1999). *Philosophy of the project 2000+ UNESCO resource kit*. Retrieved August 01, 2009 from unesdoc.unesco.org/images/0011/001180/118048eo.pdf.
Yardley-Matwiejczuk, K. M. (1997). *Role play – Theory and practice*. London: Sage.