Teaching Chemistry about 'Stevia' – A Case of Cooperative Curriculum Innovation within PROFILES in Germany

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PROFILES is a project of teacher education and curriculum innovation funded by the FP7-programme of the European Union. The aim of PROFILES is implementing innovative science teaching practices incorporating a societal perspective and compassing inquiry-based science learning. The University of Bremen, Germany, as one of the partners, combines teacher continuous professional development with the research-based design of new teaching and learning modules for science teaching. This paper presents – as an exemplary case – how the University of Bremen is operating PROFILES. This case is illustrated according to the development of a teaching and learning module on sugar and sweeteners, incorporating the use of advertising in science education.

Keywords: Chemistry education, Curriculum development, PROFILES, Participatory Action Research, Sweeteners, Stevia, Advertising

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O steviji pri pouku kemije – primer inovacije v okviru projekta PROFILES v Nemčiji

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PROFILES je projekt o izobraževanju učiteljev in kurikularnih inovacijah, ki ga je financirala Evropska unija v okviru programa FP 7. Eden izmed namenov projekta je bil vpeljevanje inovativnih pristopov v naravoslovnem poučevanju, v katere sta vključena družbeni vidik in učenje naravoslovja z raziskovanjem. Univerza v Bremnu, Nemčija, ena izmed projektnih partneric, združuje stalno strokovno spopolnjevanje učiteljev z oblikovanjem novih raziskovalno usmerjenih učnih modulov v naravoslovnem izobraževanju. V prispevku je predstavljeno – kot vzorčni primer –, kako projekt PROFILES poteka na Univerzi v Bremnu. Prikazan je primer razvijanja modula o sladkorju in sladilih z navodili za učitelje in učence, vključen pa je tudi pomen oglaševanja v naravoslovnem izobraževanju.

Ključne besede: poučevanje kemije, razvijanje kurikuluma, PROFILES, akcijsko raziskovanje z udeležbo, sladila, stevija

Introduction

One of the central foci of activity in the PROFILES-project at the University of Bremen is to associate with school reform in the State of Bremen (one of the 16 states making up Germany) in the field of science education. In 2010, the State of Bremen implemented a school reform through the establishment of a new type of secondary comprehensive school: the Oberschule. In the Oberschule, science in the lower grades of secondary education (grades 5-8, age range 10-15) combines the previously independent disciplines of chemistry, biology and physics into one subject, namely 'science'. At present, textbooks and official curriculum materials for teaching integrated science following the new syllabus are still unavailable. This means that since 2011, the science teachers in the State of Bremen have been developing their own curriculum materials for their teaching requirements.

Unfortunately, most science teachers in Bremen are not trained in more than one of the science subjects, such as biology, chemistry and physics. The teachers feel they themselves are not particularly competent and self-confident enough in developing integrated science curriculum materials, especially in the areas where they consider themselves being non-experts. The University of Bremen, therefore, took the initiative to help science teachers in Bremen in their reform and curriculum implementation efforts within the PROFILES project (Schindler et al., 2014). PROFILES-Bremen assists the reform by forming networks of teachers and helping them in the development of their curricula and teaching practices in accordance with the philosophy of PROFILES (Bolte et al., 2011). The joint curriculum development aims on contributing to teachers' continuous professional development. It takes into focus promoting teacher's self – efficacy in different identified educational areas, including the implementation of socio-scientific issues-based science education, the promotion of inquiry learning, and fostering general educational skill development (Bolte et al., 2012; Holbrook & Rannikmäe, 2012).

The central focus of the supporting activities of PROFILES-Bremen is the collaborative curriculum development of teaching and learning modules within teachers' networks. The design and developmental process is following the model of Participatory Action Research in science education as proposed by Eilks and Ralle (2002). With regard to the development of materials, the teachers meet regularly once a month in small groups (3 to 8 teachers per group) accompanied by researchers and curriculum experts from the University of Bremen. Five to six teaching and learning modules are conceived, tested and cyclically refined per year. The materials are distributed via a local website and in-service teacher training that all PROFILES teachers have access to and which are then available to be implemented by them in their classes. One exemplary case is the development of a module on sugar and sweeteners, integrating a newly developed pedagogy on incorporating advertising in science education.

Background and framework for the curriculum design

Within the PROFILES project a group of teachers suggested developing a teaching and learning module aiming at students' learning about different sweeteners (sugar, sugar-substitutes and artificial sweeteners, e.g. xylotol, isomalt, cyclamate/saccharin and aspartame) and their respective properties. The module was also suggested to focus the debate on the socio-scientific issues of healthy nutrition and the influence of advertising on student behavior. Sugar gives a lot of calories, having a calorific value of 17 kJ/g. There are alternatives to sugar, such as sugar substitutes, artificial and natural sweeteners, with lower calorific values. There are differences between sweeteners, for example in the calorific value, properties and intensity of sweetness. Artificial sweeteners, such as aspartame, acesulfame k, cyclamate, or saccharin, have practically no calorific value, while sugar-substitutes have a calorific value around 8-10 kJ/g. Due to their low physiological calorific value, sweeteners in particular are used in low-calorie diets and also by persons who suffer from diabetes. These alternative products are frequently linked to aggressive advertising campaigns and their effects softened by terms such as "sugar-free", "light" or "without any sugar".

In addition to artificial sweeteners, natural sweeteners do exist besides sugar. One of the currently most discussed groups of sweeteners is based on the Stevia plant. Stevia extracts have a very intense level of sweetness, comparable to some artificial sweeteners (about 200 times higher than sugar) (Stuckey, Lippel, & Eilks, 2012). Stevia is advertised as being a good alternative, e.g. to aspartame or saccharin, because it is plant-based and, as a result, is 'natural'. However, approval of Stevia has been the center of controversial discussions within the EU for many years. The EU prohibited its use in food and drinks for a long time. However, the EU finally approved its use in food and drinks in December 2011 (EC, 2011) and advertising instantly started referring to the 'green nature' of the new sweetener (Stuckey et al., 2012).

The questions of Stevia approval and the use of scientific arguments in advertising were suggested to allow for the module opening a broad educational focus as suggested by Sjöström (2013), or Roth and Lee (2004) by integrating a societal perspective (Ware, 2001). The students are introduced to the related controversial societal debate, as it has been proved that such authentic and controversial societal debates can be very motivating for learning science as well as very powerful for promoting general educational skills in science teaching (Marks & Eilks, 2009; Sadler, 2004, 2011; Stolz, Witteck, Marks & Eilks, 2013). The controversial debate concerns the approval of natural sweeteners based on the Stevia plant for food and drinks by the EU and potential implications (Nehrdich, 2013) as well as the use of science related information in advertising (Belova & Eilks, 2014).

The discussion around Stevia-based food and drinks is an authentic and controversial socio-scientific issue with a lot of potential to initiate learning in and beyond chemistry and science. It allows for learning about societal controversies in general (Nehrdich, 2013) and on chemistry related topics in particular (Stuckey et al., 2012). Connecting the societal controversy with authentic societal practices of information transfer allows also to learn about information transfer and information use in society, as it was suggested by Hofstein, Eilks and Bybee (2011) and later elaborated under the term 'filtered information' into different educational models (Eilks, Nielsen, & Hofstein, 2014; Marks, Stuckey, Belova, & Eilks, 2014). In this example, creating advertising was suggested by the teacher group as an authentic societal practice where science related information is selected and transformed for public use (Belova & Eilks, 2014).

As a curriculum model for integrating these different objectives and pedagogies the model of socio-critical and problem-oriented science education as suggested by Marks and Eilks (2009) was selected. The module suggest five steps to structure the learning process: (1) contextual approach and problem analysis based on authentic, everyday-life media, (2) clarifying the scientific background under inclusion of practical work, (3) resuming the socio-scientific question with respect to the initial questions, (4) discussing and evaluating different perspectives by mimicking a societal practice of information transfer and use, and (5) meta-reflection on information handling and decision making in societal controversies. This model is very much in line with the PROFILES three stage approach in which a socio-scientific issue provides the motivational introduction to the learning of science (Holbrook & Rannikmäe, 2010), but puts an even stronger emphasis on reflecting societal practices of use and potential misuse of scientific information in society.

Method

Research design

The innovation process, curriculum development and teacher training in PROFILES-Bremen are operated according to the model of Participatory

Action Research (PAR) in science education (Eilks & Ralle, 2002; Mamlok-Naaman & Eilks, 2012). This model is very much in line with the PROFILES philosophy for continuous professional development (CPD) integrating the three most effective practices for CPD suggested by Hofstein, Mamlok-Naaman, Rauch and Namsone (2012): Action Research, the teacher as a curriculum developer, and focus groups.

PAR acknowledges evidence-based knowledge from educational research and practical experience from the classroom to compose the two ends of the knowledge spectrum of teaching and learning, both of which are equally important and have their own strengths (McIntyre, 2005). Evidence from educational research and the practical experience of teachers are united through focus group discussions. Within teacher-researcher group processes, knowledge from the different domains is compared and reflected upon with respect to its relevance for innovating teaching practices in the teachers' specific educational environments (Eilks & Ralle, 2002). PAR in science education is a collaborative process of curriculum design and classroom-based research (Eilks & Feierabend, 2013). From the starting point of the focus group discussions, teachers and researchers cooperatively conceive and investigate science teaching practices. Design, reflection and research are based on a cyclical process. Module components are drafted, tested, analyzed, and revised. Central foci – as in any kind of Action Research – are the evidence-based improvement of authentic practice and contributions to the CPD of the practitioners (Mamlok-Naaman & Eilks, 2012). The teachers participating become better trained and actively involved in developing, exploring and documenting innovative teaching practices.

PAR also aims for innovative teaching concepts and materials to be widely disseminated as the end-products of this model, as well as evidence regarding their effects in class (Marks & Eilks, 2010). The accompanying research collects general evidence, which covers both the effects of changed teaching strategies and teachers' and students' personal perceptions of the new teaching approaches and pedagogies. More detailed descriptions and reflections of the design and development process are described, e.g., in Marks and Eilks (2010), Feierabend and Eilks (2011) or Eilks and Feierabend (2013). General findings encompass both justified educational strategies and practical suggestions (e.g. Stolz, et al., 2013) as well as case studies about effects of classroom innovations on student achievement or motivation (e.g. Stuckey & Eilks, 2014).

Participants

The development of the teaching and learning module on Stevia took place in a group of eight teachers working on this example for roughly one year. The group consists of teachers from various secondary schools in north-western Germany. The group met once a month for three hours to discuss their developments. Proposals were discussed during the meetings, reflected upon and revised until a rough draft of the lesson plan was ready.

To assist with the development process, several preliminary tests of specific parts of the module took place. Later reflection was based on experience and feedback from tests applying the module in its fully-developed form in different learning groups. A pilot study was conducted in the end by one of the participating teachers with the fully-developed material in two classes in Grade 7 (age 12-13 years, 31 students) at a secondary comprehensive school (Oberschule) in Bremen, Germany.

Data was collected in a portfolio by one of the teachers covering both reflections on the developmental process in the PAR group as well as experiences and observations from teaching the module in the two learning groups. Two student feedback questionnaires were applied. An open feedback questionnaire recorded students' reflections covering three open questions about (I) what they considered to be the most important thing they might have learned, (II) their opinions on the module, and (III) what they now thought about the different sweeteners in food. Additionally, a Likert-type feedback questionnaire recording students' opinions of the module was used (8 items, 4 step).

Intervention

Objectives of the teaching and learning module were suggested to be, that the students learn about different sweeteners (natural sweetener, sugar-substitutes and artificial sweeteners, such as sugar, Stevia, xylotol, isomalt, cyclamate/saccharin and aspartame), and their properties (Stuckey et al., 2012). Therefore, chemistry content knowledge was introduced through the Internet, theoretical texts and investigative experimentation to inquire into the properties of sugar as a natural sweetener, artificial sweeteners and Stevia.

Another focus of the module was suggested as aiming at students' communication and decision-making skills as seen as an integral part of 'education through science', as indicated by the 'ES' in PROFILES. Communication and decision-making skills were encouraged through discussions about authentic advertising and enhanced by learning about how advertisings are made for learning about filtered information as a contribution to promote civil scientific and critical media literacy (Belova & Eilks, 2014).

To emphasise the societal importance of the topic and the focus on advertising, the scenario for the module presents five advertising spots from the Internet concerning different sugar-free sweets. The students make notes regarding the intentions of each spot. Students are asked to search for similarities and differences. To discern the personal connection of the topic with the students, the teacher presents various statements and the students physically assign themselves to one of two signs which are placed in the classroom: "for it" or "against it". Examples of the different statements are:

1. I would buy more sugar-free than ordinary food with sugar in it.
2. Sugar-free products are more healthy.
3. Sugar is a better option, because sugar is a natural substance.
4. I buy many things which are advertised on TV or Internet.
5. …

From this activity, different questions are derived. One group of questions regularly relates to issues of chemistry behind the adverts. These questions are used for motivating investigation of the properties and caloric value of the different sweeteners used in the sweets described as 'light'. Comparison of the substances and properties is initiated by giving each pair of students two similar sweets – one containing sugar, the other one is sugar-free. The students are asked to investigate the ingredients from the list of ingredients specified on the package. The students find out the sweetening components by using a list of potential sweetening ingredients and respective theoretical resources on the Internet.

The learning of the theory aspect in respect of sugar, sugar substitutes and sweeteners, including their current uses, is performed by a jigsaw classroom (Aronson et al., 1978). The investigation of the properties of the different sweeteners is operated in the lab in accordance with the learning-at-stations method (Eilks, 2002a). In the learning-at-stations different experiments inquiring sugar, sugar substitutes and sweeteners are offered at stations and can be conducted by the students in the sequence and intensity of their choice.

To switch from learning the science aspect back to the societal debate on the use of sugar, sugar-substitutes and the different sweeteners, the students return to the initial confrontation with the adverts. It is ascertained which questions concerning the adverts are already answered and which are not. The students are then asked to create their own advertisements. They are divided up into small groups, each given the task of producing an advertising leaflet (in paper size A5) by working on the substances xylitol, isomalte, Stevia, sugar and saccharin/cyclamate. To create their advertisements, each group of students is provided with a list of arguments containing the pros and cons regarding 'their' sweetening substance as described in Belova and Eilks (2014). The students then prepare a table containing only the pros because only these aspects should appear in the advertising. The students are asked to compile positive arguments which they consider have the highest potential to be used in advertisements. The students then produce their own advertisement (on paper or computer). When doing this, the students have to consider the speed of awareness, comprehensibility, illustration, and also consider the presentation format, colours and appearance. During the presentation of the adverts, the students are asked to outline the reasons for their decisions, highlighting which arguments are used. The students are asked to justify why they have chosen these arguments and not others. The students also discuss the meaning of their choice with respect to making an attractive advertisement.

The module ends with a meta-reflection about the processes leading to the students' adverts. The discussion concerns the criteria by which information for advertising is selected and filtered and how we can treat this information as critical consumers. The class considers what amount of science and chemistry-based information is used in the adverts and whether it is deemed helpful to use science and chemistry-related information in advertising for different products. A discussion is also encouraged concerning how scientific literate an informed citizen needs to be to recognise the science and chemistry aspects in adverts and how to deal with this. Table 1 provides an overview of the module.

Table 1. *Overview of the module*

Stages of the module	Task
Textual approach and problem analysis	– Watching advertising spots about "sugar-free" sweets – Reflecting own positions on different statements – Comparing sugary and sugar-free products by inquiring the declaration of the ingredients on the packages
Clarifying the chemistry background in a lab environment	– Jigsaw classroom and learning-at-stations: Theory learning and making different experiments and investigations on various sweetening substances in small groups
Resuming the socio-scientific dimension	– Reflecting which aspects of the topic were answered, and which were not
Discussion and evaluating different points of view	– Preparation of own advertisements for different sweetening substances in small groups - Presentation of the different advertisements and explanation why specific arguments were chosen for the advertisement and others were not
Meta-reflection	– Reflecting how advertisings are made and which role scientific information plays in the creation of different advertisings

Findings and discussion

To date, the fully-developed teaching and learning module has been implemented in several lower secondary learning groups. As part of the PROFILES strategy for evidence-based continuous professional development and reflective practice (Hofstein et al., 2012), one of the participating teachers did a case study in two relatively lower achieving Grade 7 science classes in the Bremen Oberschule (age range 12-13; 31 students). The lessons were reflected in a teaching and learning portfolio about the module by the teachers. Two feedback questionnaires were used to ascertain the students' view of the topic and the module. The questionnaires consisted of open and Likert-type questions.

In the reflective teacher portfolio, the use of advertising as an introduction to science teaching was described as having been very authentic and motivating. The discussion on the 'light' products was considered highly motivating for the students (see also Marks, Bertram, & Eilks, 2008). From the view of the teacher, it was obvious that the students had a great deal of fun in analysing the adverts provided and creating their own. The activities around the advertisements led to very intensive discussions on the arguments to use. The teacher considered that the students generally liked the teaching module.

In the open questionnaire, the students were mainly positive about the modified teaching methods. The inquiry nature of the module, the open pedagogy of the experimental phase and the creative challenge during the production of the advertisement were also found as being very positive. In the students' opinion, the module was not 'just' pure science, which is something that they were very positive about. The students also enjoyed the cooperative character of the teaching and learning module, e.g. carrying out experiments. Criticism was rare and mainly touched the question of demands in reading and writing. This criticism could be justified because these learning groups had a high proportion of students with a non-German speaking migration background and were considered by the teachers, on average, as having great deficits in the use of the German language.

The Likert-items support both the point of view of the teacher and the summary of the student feedback to the open questionnaire (Figure 1).

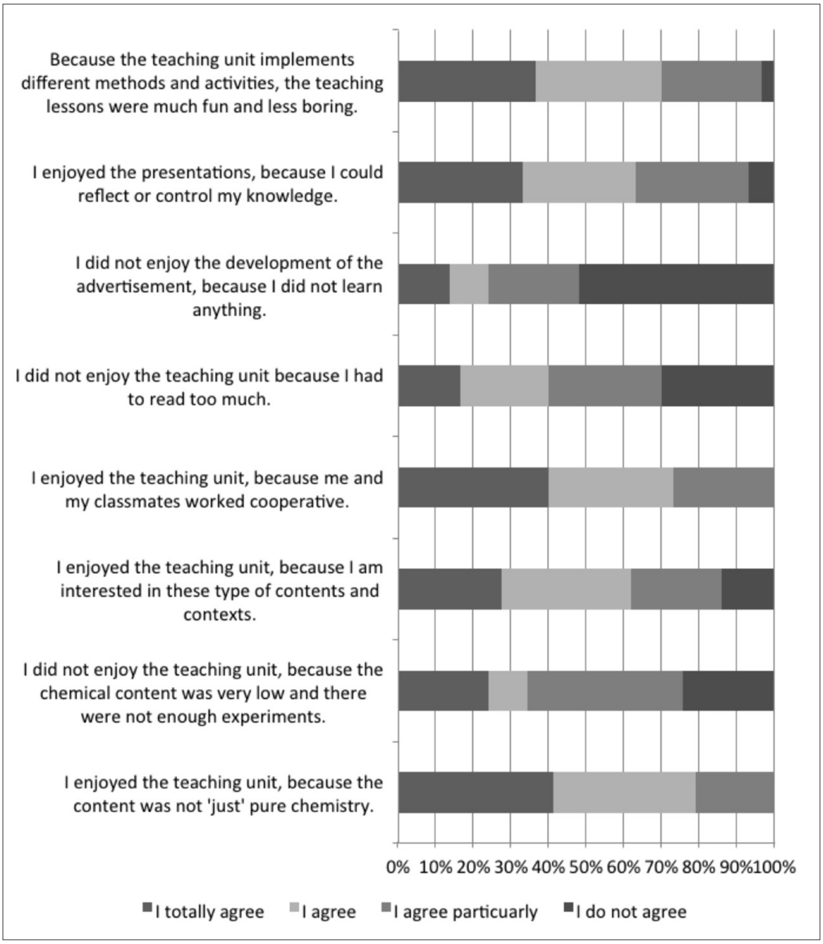

Figure 1. Results of the questionnaire regarding the module 'Stevia'.

Implications

From the example, it appears that the PROFILES philosophy of inquiry-based and societal-oriented science teaching (Holbrook & Rannikmäe, 2012) encourages students' motivation in science lessons. These findings support experience gained in similar modules, e.g. teaching about fats and carbohydrates using the debates surrounding different types of diets (Marks, et al., 2008), environmental and health issues surrounding musk flavours in shower gels to learn about fragrances, cosmetic products and tensides (Marks & Eilks, 2010), tattooing (Stuckey & Eilks, 2014), or implementing the debates on climate change and alternative fuels for cars in science classes (Eilks, 2002b; Feierabend & Eilks, 2011).

The case proved that it is basically the authenticity and relevance of the topic and the sharing of social communication processes as an essential part of the PROFILES philosophy that made science education in this example relevant in the eyes of these relatively young and, on average, lower achieving students (see also Stolz et al., 2013; Eilks et al., 2014; Stuckey & Eilks, 2014). The use of advertising as an additional motivational pedagogy for science lessons is still rare (Belova & Eilks, 2014). However, used as a tool to learn about filtered scientific information in public debate (Hofstein et al., 2011) it proved to be valuable to enliven the pedagogy of societal-oriented science education and contributed to the perception of relevance of science education in the eyes of the students.

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