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TEACHING '*BIODIESEL*': A SOCIOCRITICAL AND PROBLEM-ORIENTED APPROACH TO CHEMISTRY TEACHING AND STUDENTS' FIRST VIEWS ON IT

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ABSTRACT: A method to improve student motivation and attitude toward school science teaching may be to design lessons related to societal issues such as the actual and potential industrial applications of science and technology. This paper presents a teaching approach for the production of diesel fuels (*biodiesel*) from vegetable oils (rape seed oil). In addition it attempts a small evaluation by discussing students' answers to just two simple questions on the method used. The objective was to determine whether student sociocritical reflection on the applications of scientific discoveries may improve their attitude towards science learning, their communicative skills and their personal development. [*Chem. Educ. Res. Pract. Eur.*: 2002, *3*, 77-85]

KEY WORDS: *sociocritical chemistry teaching; problem-oriented chemistry teaching; attitudes*

INTRODUCTION

Studying science is not very popular in many countries (e.g. Lazarowitz *et al.*, 1988, Becker, 1994). Among others, one reason is considered to be that scientific knowledge is taught with an approach that is too content driven and which emphasises the systematic treatment of science too strongly (e.g. Johnstone & Reid, 1981; Becker, 1994; Lijnse, 1995; Donelly, 1999; Osborne, 2001). Therefore, science lessons and science itself do not seem to be relevant for the students, because they cannot grasp their usefulness for their everyday lives or for their future (e.g. Holbrook, 1998; Osborne, 2001). This supposed lack of relevance leads to low motivation and a lack of interest in science and science learning (Osborne, Driver, & Simon, 1996).

A potential way to improve student motivation in school science teaching (which increasingly is considered to be an integral part of science education) may be to design lessons that include discussions about societal issues related to science and about the actual and potential industrial applications of science and technology (e.g. Johnstone & Reid, 1981; Bybee, 1987, 1993; Solomon & Aikenhead, 1994; Millar, 1996; Jenkins, 1997; Sjoeberg & Kallerud, 1997; Osborne *et al.*, 1998; Holbrook, 1998; Osborne, 2001). Such an approach may also improve students' attitude towards science (e.g. Osborne, Driver, & Simon, 1996, 1998), and through attitude achievement (Simpson *et al.*, 1994).

This paper presents a teaching approach for a series of lessons on a useful application of chemistry: the production of diesel fuels (*biodiesel*) from vegetable oils (rape seed oil) (Eilks, 2000a; 2001). In addition it attempts a small evaluation by discussing students' answers to just two simple questions on the method used. The students were asked to reflect on the main goals of the teaching, what they learned and how they liked the activities. The objective was to determine whether student sociocritical reflection on the applications of scientific discoveries may improve their attitude towards science learning, their communicative skills and their personal development.

TEACHING *BIODIESEL*

In most cases, German curricula are reformed by revising the table of contents in the official syllabus. Each of the 16 states (*Länder*) within Germany has its own official syllabus, different e.g. for grammar, middle, or comprehensive schools. Developing completely new curricula that use different teaching methods, as is common in the U.S. and UK, and the inclusion of new textbooks and teaching materials, (e.g. The American Chemical Society, 1998; Burton *et al.*, 2000) is not at all common in Germany. Thus, in more and more governmental curricula for the German *Länder*, topics concerning renewable energy sources were included only by defining them as new scientific content in the syllabuses.

One of the renewable energy sources most students are familiar with is the use of rape seed oil for the production of diesel fuels (*biodiesel*). In teaching practice in Germany as well as in most textbooks and syllabuses, this topic is generally approached from a purely 'chemical' point of view. Questions about whether or not scientific and technological developments are of benefit to society and about their ethical, ecological and economical value are sometimes mentioned, but they are not meant to be discussed any further in science lessons. In this work, students worked on the positions of different pressure groups, while opportunities were provided for broad discussion and controversy about the ecological and economical value of biodiesel. We consider that this approach constitutes a "sociocritical and problem-oriented approach to chemistry teaching" (Eilks, 1999; 2000; 2001). The unit has been structured to supplement the regular lesson plan in grades 10-12 (age range 16-18), and consists of 9 lessons (of 45-minutes duration each). The teaching method was applied several times at German grammar and middle schools in grades 10-12 (age range 16-18).

Starting a lesson by gathering students' prior knowledge is considered to be extremely important (e.g. Lijnse, 1995). Accordingly, teaching biodiesel began by showing the students various stickers, which are commonly available as advertisements at petrol stations in Germany. The students were asked to share what they already know about biodiesel and their previous experiences with the topic. This discussion was supplemented by analysing additional authentic advertising materials. Two main subjects were mentioned by the students that seemed to be the most relevant to their everyday lives: 'the technical use of biodiesel in comparison to crude oil based diesel fuel' and 'the reflection on the ecological effects of its production and use/ecobalance'. This introduction, based on authentic materials, gave the students the opportunity to pose a lot of interesting questions about the topic, including questions about the chemistry of production and technical use.

Three teaching phases followed:

Phase 1. This took three lessons (45 min. each) during which students learned about biodiesel by carrying out various experiments and reading prepared texts. A form of cooperative

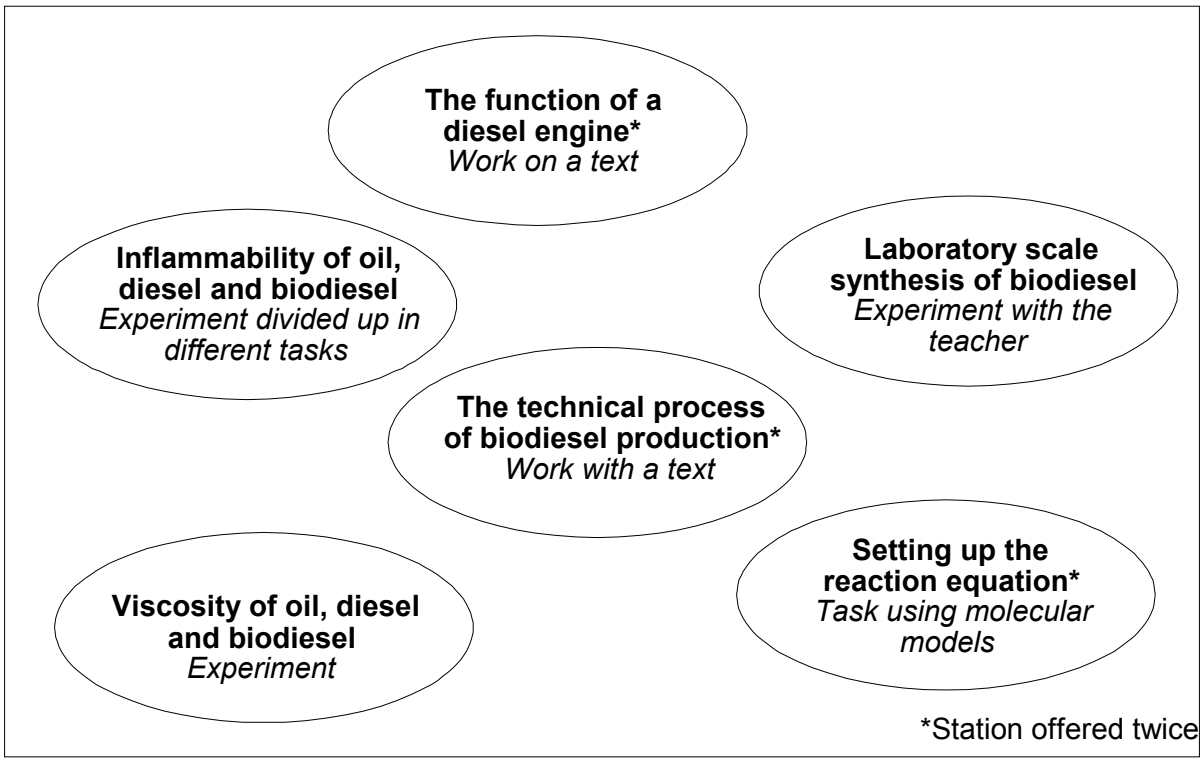

FIGURE 1. *'Learning at stations' on the fundamentals of biodiesel science, production and use.*

learning known in Germany as 'learning at stations' (*Lernen an Stationen* or *Lernzirkel*) was applied (Eilks, 2000a; 2001; 2002); it leads to high student activity and allows for differentiation among the students. Several stations are available in the classroom, offering a variety of activities that focus on parts of the common task. The students visit these stations in small groups of three or four in any sequence and time they choose; in this way, they are partially responsible for organising their work. The stations and activities were: the chemical structure of the product and the reaction equation (models), laboratory scale synthesis (experiment), industrial production (text), flammability (experiment), viscosity (experiment), and the function of diesel engines (text) (see Figure 1). In order to make informed decisions about the application of science and technology, this working on the chemical and technological background has been described as important, before the discussion about the value of this technology will start (Ratcliffe, 1998); it also contributes to positive attitude (Johnstone & Reid, 1981).

Phase 2. The question of ecological evaluation was introduced using a short newspaper article about a public debate under the headline 'Biodiesel - An environmentally friendly alternative?'. But, even in this short article, several totally different opinions related to the title question were presented, which were representative of the views of various pressure groups. It was recognisable for the students that only a limited number of arguments were presented for each group in the article, so that a thorough examination and consideration of the positions was not possible.

The term 'ecobalance' was mentioned in the article, but without a definition. In a German Institute for Standardisation publication (DIN, 1994), the students were able to work out the meaning of 'ecobalance' and the fundamental principles of this concept: the idea of

evaluating all ecologically relevant effects of a product during its entire life (cradle-to-grave analysis). They also recognised a few obvious problems, e.g., problems with quantifying, weighing and comparing the ecological effects and the raw material consumption.

It is not possible to conduct an ecological balance analysis for such a complex field like the production and use of biodiesel in a school setting. However, it is possible to discuss studies that have been conducted professionally. Following Ratcliffe (1998), this seems to be helpful to lead to a better organised discussion compared to in an open framework lacking the structure of given positions. Thus the students were asked to analyse respective texts in groups of five students. Texts had been produced by the Society of Crude Oil, Gas and Coal Research (Drechsler *et al.*, 1994), the Society for Development Technology/Union for Promotion of Oil and Protein Plant Production (GET/Ufop, 1995), the German Shell (Schnieder *et al.*, 1992) and the Foundation for Preserving Nature (Schmitz-Schlang, 1995). These texts were prepared by shortening them to a length of about four pages with only minimal changes in their content and choice of wording (Eilks, 1999). The students were also allowed to use the original publications, to demonstrate their authenticity. They were asked to analyse the materials and required to provide a short, 5 to 10 minute, report on the position described. An exchange of information between the groups was prevented as much as possible. This phase of cooperative work together with the introduction of Phase 2 lasted for four lessons (45 min each).

Phase 3. In the final phase, the students presented the different positions they had worked on. A comparison was developed on the blackboard (see Table 1). The students were asked: (a) to recognise the large differences in the positions and the arguments chosen to support them; (b) to take into account that the results of the studies depended on the interests of the authors or pressure groups that had produced them; (c) to express their insights about how necessary it is to have comprehensive information on different positions as well as scientific knowledge of the subject (compare Ratcliffe, 1998).

TABLE 1. *Different positions on biodiesel use and presumed background of the authors/sponsors as worked out by the students.*

Pressure group	Conclusion	Presumed background
Society for Crude Oil, Gas and Coal Research	Only little potential of reducing greenhouse gas emissions, but high costs and also additional waste emissions.	Promotion of crude oil products.
Society of Developmental Technology	High potential in reducing carbon dioxide, an economically sensible system.	Promotion of fuels based on renewable energy sources, esp. biodiesel.
German Shell	Recognisable potential for reducing greenhouse gases but only in a system based on subventions, use of vegetable oil or biodiesel as fuel additive seems to be more effective.	Promotion of crude oil products and biodiesel as an additive for conventional diesel fuels.
Foundation for Preserving Nature	More emissions of greenhouse gases and a considerable burden for the environment, reduce energy consumption instead.	Promotion of techniques for reducing energy consumption, promoting organic agriculture.

STUDENTS' VIEWS: METHOD

The results presented in this paper are based on lessons taught by the author to a class of nineteen students (nine girls and ten boys), at one grammar school in the north of Germany in regular, grade-11 chemistry (Eilks, 1999). In this grade, the focus is on the descriptive chemistry of classes of organic compounds. Thus, the topic 'biodiesel' followed the units on simple organic compounds, alcohols and organic acids.

At this point, it must be emphasised that in Germany forms of cooperative and 'open' (see below) learning are rarely applied. Chemistry teaching is generally teacher-centred: the teacher is organising the content of the teaching and decides on all activities in the classroom; as a rule, the teacher stands in front of the whole class, demonstrates and explains the lesson. In the so-called 'problem-oriented phases' (*problemorientierter Unterricht*) the problem is usually given by the teacher, and is not authentic; further, the process of problem-solving is often strongly guided by the teacher. Such teaching methodology was used with the class of this study, until the author of this paper took over teaching, and started using more 'open' methodology. In Germany, 'open' (*offen*) teaching provides students with some freedom to follow their own interests, while they are partially allowed to make decisions about their learning process. This concerns both the content and the activities. Note that teaching the unit on 'biodiesel' started three months after the author undertook teaching in this class. The students of this study had one 'learning at stations' experience on the topic of simple organic acids a couple of weeks before the teaching unit on biodiesel began (Eilks, 2000b; 2002).

In order to assess whether these students learned about the social aspects of science and the relationship between science, society and technology, a formal evaluation was conducted. Parts of the Views on Science-Technology-Society (*VOSTS*) test, developed by Aikenhead and Ryan (1992), might have been used here, but for various reasons they were not: problems can occur when this test is applied (Aikenhead & Ryan, 1992), while it is difficult to be used in classroom; in addition its translation into German would cause further problems (Johnstone and Reid, 1981).

In this study, students were asked instead just two simple questions:

Question 1: *What are the main things that you learned in the chemistry lessons in the last three weeks?*
Question 2: *What do you think of the chemistry teaching in the last three weeks?*

The first question intended to find whether the students mentioned the design of the lessons and general learning goals, such as communication and social skills, personal development and self-organised learning. The question was not formulated specifically about the teaching goals, but about the 'things' that they thought to have learned. The question left it up to the students to provide answers concerning scientific contents, or the nature of the activities, or their abilities in the field of communication, social skills and personal development.

The second question focussed on determining students' acceptance of this kind of chemistry teaching and provided more opportunity for reflecting on the more affective aspects of their experience. More specifically, the question can be interpreted as follows: is this type of chemistry teaching considered interesting? Are the topic under consideration, as well as the general teaching objectives of this approach mentioned by the students and considered to be personally relevant?

STUDENTS' VIEWS: FINDINGS

Question 1

(*What are the main things that you learned in the chemistry lessons in the last 3 weeks?*)

Students' answers can be classified into three main groups:

(a) Answers that dealt with pure scientific content, such as chemical synthesis, industrial production or technical use.
(b) Answers that were concerned with biodiesel, and dealt with their reflection on the ecological value of the technology and the discussion about the use of biodiesel in society. Such answers show that the lessons supported the development of a critical consciousness about this specific application of chemistry and technology, e.g., the use of biodiesel is a difficult issue when faced by an individual.
(c) Answers that dealt with aspects of learning that are not dependent on the biodiesel topic, such as communication and social skills or personal development.

Table 2 shows the frequency of the three types of answers. No student limited his or her answer to only mentioning scientific content (a). All 18 students mentioned aspects from categories (b) and/or (c). 15 out of 18 students felt that the most important thing that they learned was to become more aware of both positive and negative sides of the use of chemical products and the difficulties in evaluating their use for both the individual and society (answers containing aspects of category (b). In addition, 10 out of 18 students said that they learned things that were of general interest to their personal development (answers containing aspects of category (c). Of these, the aspect mentioned most often (by 7 students) was that they learned to form their own opinion using analysis and consideration of and reflection on different positions and that they learned how to evaluate those positions in light of their own interests.

TABLE 2. *Frequency of the three types of answers to question 1 (see text).*

Type of answer	Number of students (total $N = 18$)
only a	-
only b	4
only c	2
a and b	4
a and c	1
b and c	2
a, b, and c	5

Typical examples for students' views on the overall learning effect of the unit are:

"We debated the use of biodiesel, so that now we can make up our own minds and argue for our own position using our knowledge (about production, properties, ...). In addition, we learned something about self-organised learning, which I feel was extremely positive. Also, the group work encourages each member of the group to fulfill the requirements each time."

"I learned a lot about the production, structure, use, advantages and disadvantages of biodiesel. Also, I consider it to be important that I learned about our environment and its

protection. I especially learned about how companies sell environmentally friendly products and how naive we can be if there is the syllable 'bio' in it."

"I have learned about the advantages and disadvantages of biodiesel, about interests of pressure groups and how to evaluate their opinions by considering their particular interests, and how to develop an opinion and make up my own mind."

Question 2
(*What do you think of the chemistry teaching in the last three weeks?)*

This question was interpreted in two ways: (a) Is this type of chemistry teaching estimated as interesting and is recognisable that the topic and the general aims of this teaching approach are mentioned as personally relevant; (b) Is this type of chemistry lesson attractive because of the chosen methods and the activities they participated in?

(a) *First interpretation*: Seven students mentioned that they found the teaching approach to be interesting, informative or up-to-date. Beyond these comments, a sense of personal relevance was not recognisable. Nine students mentioned that they found the lessons interesting, but they also said they found it of personal importance for them: five students mentioned aspects such as discussing a problem or how to act in everyday life; and four students mentioned the aspect of making up their minds and fighting for their own opinions. So, altogether 16 out of 18 students found the topic and this method of teaching to be interesting and/or personally relevant. Here are a few typical answers:

"I found the chemistry lessons in the past three weeks to be really much better. The topic had to do with everyday life and I can say that this information about biodiesel taught me a lot. Now I can make up my own mind about biodiesel because I'm aware of a lot of facts and points of view. I can do quite a lot more with this topic."

" I find this kind of chemistry teaching to be far more interesting simply because this topic is one that, though it may not have been that interesting at the start, got more interesting because we became more and more aware that the topic affects us personally (e.g. as a car driver, voter)."

"We have learned to work out something on our own and to deal with different points of view. We had to make up our minds about our own position and give reasons for it, and we were not influenced in any one direction."

(a) *Second interpretation*: Six out of the eighteen students mentioned the methods. Of these, five students mentioned that they liked self-organised work in small groups and four mentioned that they found the opportunity to prepare and present reports and participate in discussions to be positive elements of the lessons.

CONCLUDING REMARKS

The chemistry teaching method described here for the topic of biodiesel (Eilks, 2000a; 2001) aims to foster controversial discussions in the classroom. It provides a potential way for increasing students' motivation and attitude toward chemistry and its importance to society. The findings are consistent with observations made previously that attitude development does occur when students are allowed to interact with issues (e.g. Reid, 1980). Most of the students evaluated here were participating in the last chemistry lessons that they

will ever have. Even so, most of the students were considered by the teacher as very motivated and participated actively in the lessons.

The evaluation confirms observations made by different teachers who taught this unit several times in their courses from grade 10 to 12 using the published teaching material (Eilks, 1999). Teachers reported very intense discussions and that students showed their astonishment that it was possible that so many different evaluations existed for the same scientific topic.

One teaching unit, even if it lasted several weeks, can only have a small impact on the learners. It is encouraging to note their reactions to the taught unit, as well as that they felt they had derived benefit. In particular, the fact that the students mentioned their awareness of the relevance of chemistry applications for the individual, and of how difficult it is to evaluate what scientific and technological applications mean for society and their everyday lives, can be considered encouraging.

Classroom discussions about chemistry and its uses seem to be an activity that helps teachers take a few small steps forward. They should be actively integrated into scientific teaching as a way of strengthening student acceptance and fostering a more informed view of the importance of chemistry. Taking these steps is considered as a help to increase the relevance of chemistry lessons from the students' point of view and help teachers to achieve their educational objectives in the fields of social and communicative skills and personal development.

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