TEACHING CHROMATOGRAPHY IN SECONDARY SCHOOL – AN INVESTIGATION CONCERNING GRADE, CONTEXT, CONTENT, EXPERIMENTS AND MEDIA

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Abstract

This investigation focuses on how one of the best established and most efficient methods for the separation of substances – chromatography – is taught in secondary school. A questionnaire-based study with teachers (N=76) was used to get a first glance at the situation in schools. The results show that various chromatographic techniques (PC, TLC, GC, HPLC) are taught in secondary school using different context settings. All teachers use paperchromatography as a students' experiment analyzing e.g. colour pens in 7th grade. A far less amount of teachers cover more complex techniques such as gas chromatography e.g. in 12th grade. A detailed insight was attained by analyzing 37 chemistry lessons of 18 classes in 7th grade. It could be shown that a broad variety of experiments, remarkable differences in the use of scientific concepts to explain how chromatography works and in the application of media occure.
Key words: *chromatography, adsorption, solubility.*

Introduction

The OECD demands that "teaching should [...] concentrate more on scientific concepts and methods rather than on retaining information only" (OECD, 2006). Apart from curricular changes and the development of new teaching material, this request also leads to the question of how methods are taught at all in school.

For the investigation of this question we chose the technical method chromatography, as it is one of the best established and most efficient methods for the separation of substances. This importance is underlined by the fact that chromatography is the sector with the second highest profit volume in analytical chemistry (Böcker, 1997). Less complex chromatography methods such as paper chromatography are for example an element of the German curriculum for chemistry education in secondary schools (Ministerium für Schule und Weiterbildung des Landes NRW, 1999) or a part of Science education at key stage 3 according to the National Curriculum for England (Department for Education and Skills, 2004). Although chromatography plays an important role in scientific practice and chemical education, there is a lack of knowledge about the impartation of chromatography in school science.

To explore these issues two projects have been realised:

1. Questionnaire-based teacher study to get a first glance at the situation in schools
2. Analyses of chemistry lessons

Questionnaire-based Teacher Study

Analyzing the curricula leads to an overview of possibilities to integrate the topic "chromatography". In Germany this would be in the area of "the separation of substances" in 7th grade and in 12th grade working on "methods of analytical chemistry". But this does not give information about whether chromatography as a method is also used in the field of other topics e.g. pigments and dyes. This question can only be answered by the educators themselves.

Therefore a questionnaire-based study with chemistry teachers was chosen to get an overview of which techniques of chromatography are taught in schools.

Methodology of research

A questionnaire was designed using open and closed questions to investigate the issues described above. In this questionnaire the teachers were asked to give information about their gender, their degree, the type of school they are working in, their other subject and the amount of years of teaching practice. Concerning chromatography the techniques paper chromatography (PC), thin layer chromatography (TLC), gas chromatography (GC) and high pressure liquid chromatography (HPLC) and a free space to add any other technique were given. The teachers were supposed to indicate which techniques they teach at all, then give further information about the grade, the curricular context and if they use an experiment. They were asked to write whether it is a students' experiment, a student or a teacher demonstration.

The teachers could either fill in their contact information for further projects (e.g. the participation in the chemistry lesson analysis project) or return the questionnaire anonymously. All together 235 questionnaires were sent to chemistry teachers in North Rhine-Westphalia (NRW), Germany. The return rate of this survey was 32 %.

Results of research

As shown in figure 1, all teachers usually deal with the technique of paper chromatography in the chemistry lessons of 7th or 8th grade.

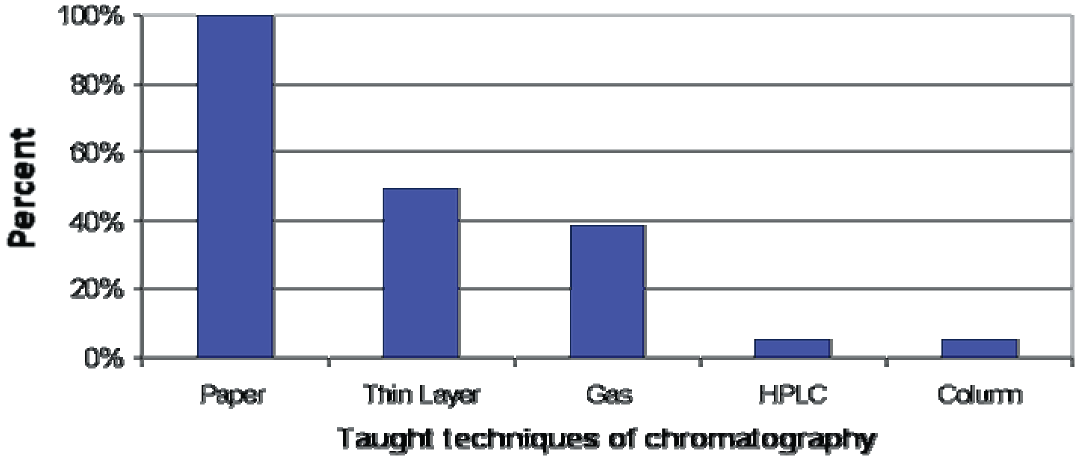

Figure 1. **Column diagram showing which techniques of chromatography are taught in school.**

The most often mentioned application of the paper chromatography technique is the separation of pen colours. This experiment is also the most frequently published application for paper chromatography in school books in NRW (Schleutker, 2006). The modern, more expensive and complex techniques such as gas chromatography are taught more rarely, even though 50% of schools have the equipment to perform thin layer chromatography and a third of the schools possess the facilities for gas chromatography (Tausch & Weber, 2002).

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Paper chromatography is taught using a students' experiment. In contrast the more complex chromatography techniques are usually not performed by students. These methods are taught only in theory, sometimes supported by models or film or presented as a student or teacher demonstration (Figure 2).

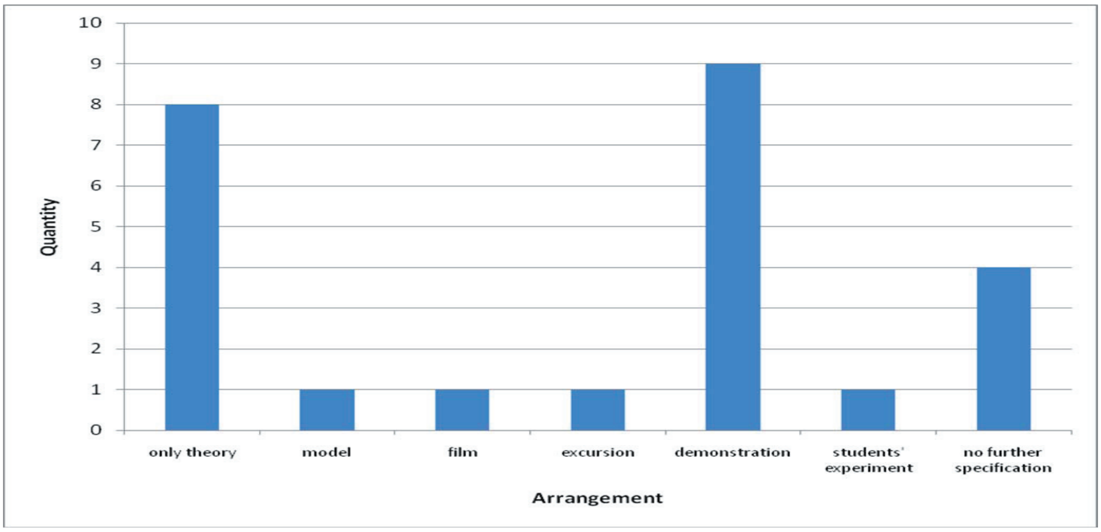

Figure 2. Media used to teach gas chromatography.

There is a tendency that teachers with another qualification such as a degree in science degree or a PhD more often teach more complex chromatographic techniques. The overall proportion of teachers with such qualifications is 34 % in the survey. Compared to that 50 % of the teachers who teach gas chromatography have such qualifications.

Analysis of Chemistry Lessons

This study wants to get an insight into real chemistry education in schools concerning chromatography. The best way to collect data on this area is to observe actual chemistry lessons.

The results of the teacher survey led to the decision to begin the study in the 7th grade (age 12 to 13 years). At this early stage chemistry is an obligatory subject for all students. Chemistry classes in Germany are optional at higher levels and therefore any study at this point would not represent a part of science education all students achieve.

Methodology of research

After an information session, 15 teachers volunteered to invite observers to their chemistry lessons concerning chromatography and this lead to the observation of 37 chemistry lessons in 18 different classes. The observations of two independent observers were recorded in written protocols and analysed following the rules of qualitative content-analysis in general and specifically by forming inductive categories (Mayring, 2007). This led to focusing on the aspects context, the kind of students' experiment, content and media of process representation.

Results of research

- Context

  In four of 18 classes the students' experiment was imbedded into a story of a cheque fraud. So the experiment was introduced using real life application. In six classes the aim of the experiment was stated as finding out whether the object is a mixture or a pure substance. Three other classes were told that the separation of substances is the goal of the experiment. The investigation of the presented objects (felt pens or sweets that contain food dyes) was the introduction for the lessons of three classes. One class started immediately with carrying out the experiment, while another class got was told the topic paper chromatography before they started working.

- Kind of students' experiment
  A broad variety of students' experiments could be observed. Although most of them (e.g. Figure 3 B-D) aim to separate pen colours, they all differ in technique [PC (A-C); TLC (D)] and arrangement [circular (A,B); ascendant (C,D)].

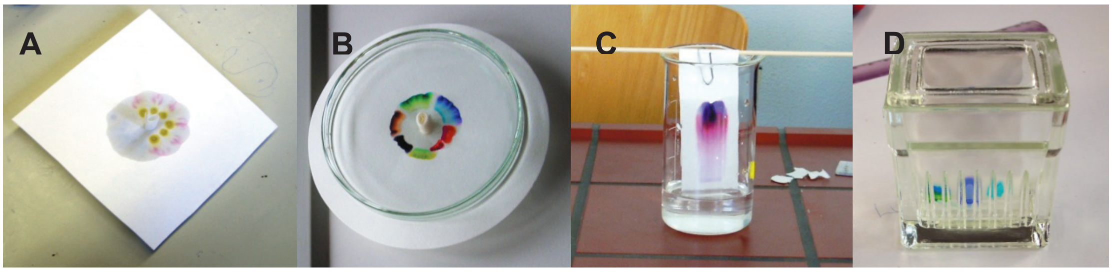

Figure 3. Examples of students' experiments in chemistry lessons.

All classes performed at least one students' experiment. One of the classes carried out a paper chromatography first and after that performed a thin layer chromatography. Table 1 shows an overview about the observed techniques, arrangements and used examples.

Table 1. Overview about the observed types of chromatography.

Chromatographic technique	paper			column	thin layer
Arrangement	ascendant	circular		ascendant	ascendant
Example	felt pens	felt pens	food dyes	felt pens	inks
Quantity	6	10	1	1	1

- Content
  Analyzing school books (Schleutker, 2006) as well as chemistry lessons concerning chromatography led to three main content criteria – Solubility, adsorption and the submicroscopic level. With the help of the criteria solubility and adsorption the scientific concepts that are used to explain the process can be identified. Discussing the process on the submicroscopic level can be considered as an indication for a more detailed insight into the process. While all teachers use the concept of solubility to explain the chromatographic separation process, one fifth of the explanations lack the concept of adsorption. Important is also the fact that the scientific term "adsorption" is circumscribed in most of the classes as sticking power. The quantity of combinations of these main content criteria is shown in Figure 5.
- Media for process representation
  Another obvious difference between the observed chemistry lessons was the application of media for process representation. Two different kinds of media could be distinguished – verbal and graphic.

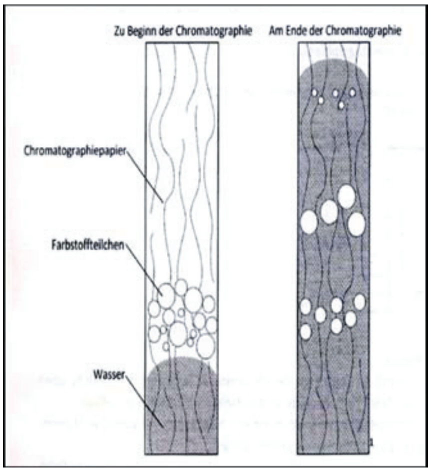

Figure 4. **A graphic medium for process representation.**

The verbal kind of media does not actually visualise the chromatographic process. In four classes a kind of fairy tale analogy was used. The different molecules were compared with men who could either hold on to wooden pole or get carried away by the river. In one class a story more connected to everyday life was chosen. Here the image of a running competition was used to support the understanding of the submicroscopic processes. Another teacher divided the class into different groups who should imagine that they were dye particles, paper particles or water particles and describe how they would interact with each other. An example for a real visualisation and therefore a graphic medium for process representation is shown in Figure 4.

With the help of content criteria solubility, adsorption and submicroscopic level as well as the use of media for process representation the observed chemistry lessons could be categorised into different types, as shown in Figure 5. Each minus sign indicates that the corresponding content criterion was missing. Following the branches of the diagram the observed combinations and their quantity can be identified.

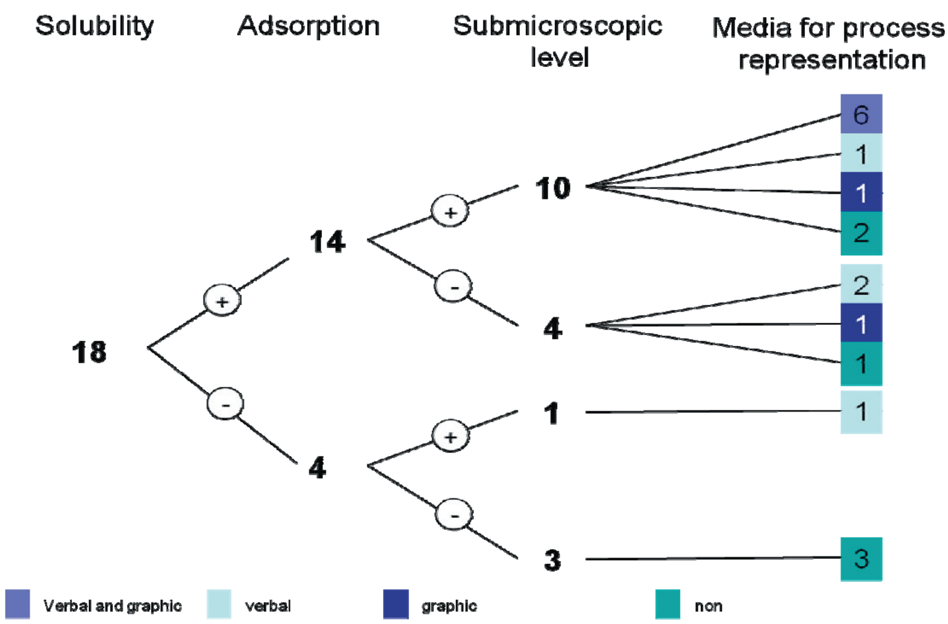

Figure 5. **Types of observed chemistry lessons.**

Discussion

It could be shown that there is a gap between modern research methods and school science concerning chromatography. Chromatography is introduced at a very early stage in chemistry education in Germany. And not all teachers use this technical method again at a higher level. It can be assumed that a remarkable amount of German students are taught chromatography only at a stage where basic scientific concepts have just been introduced. This leads to the question whether the interactions which lead to the separation of substances during the chromatographic process can be understand in this phase of chemistry education.

The analyses of chemistry lessons showed how chromatography is taught in school at this early stage. Key aspects for the comparison could be identified. Investigating those key aspects led to insight into how differently chromatography is taught in school. It could be shown that not in every class all relevant scientific concepts of chromatography are discussed.

Conclusion

The knowledge about the gap between modern research methods and school science education is useful to institutions that offer lab projects for schools such as university labs or science centres. By designing lab projects to support teachers who are willing to teach modern yet expensive methods the gap could be bridged. For example these results led to the development of a new project on gas chromatography using lavender for the Alfried Krupp-Schülerlabor (Schuhmann, 2009).

Further investigations will show whether the different types of lessons lead to different levels of understanding concerning the operating mode of chromatography. The analyses of the lessons provide a standard for each type of chromatography lessons against which the students' achievement can be measured.

If the lessons are as different as in this case, the students' achievements are highly connected to the lessons they have attended and not only to their cognitive abilities, interest or motivation. For example, a student in an assessment might only use solubility to explain chromatography and thereby stay on the macroscopic level because that covers all the student was taught about chromatography (bottom branch in Figure 5). As the differences in teaching chemistry are probably not limited to chromatography, the observation and analysis of real school lessons are obligatory if one wants to investigate or even measure students' knowledge.

Out of school learning facilities which provide projects with elements that built up on the fact that students already know about the operating mode of chromatography should be aware now of the broad variety of lessons the students might have attended.

Assuming that substantial differences in chemistry education at this early stage occur not only under the topic chromatography the realisation of the intention to provide all students with basic scientific literacy in chemistry is put into question.

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