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GROUP DISCUSSIONS AS A TOOL FOR INVESTIGATING STUDENTS' CONCEPTS

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ABSTRACT: Learning chemistry, i.e. acquiring and changing chemical concepts, is a complex process. Investigating these processes is a complex task. Therefore, a variety of methods is necessary to provide relevant research results. The present paper explores the possibility of conducting discussions with entire chemistry classes in such a way that students are given a stronger role. The investigation tries to develop a structure for group discussions, guidelines for the role of the host as well as for the analysis of the discussions, and examples for stimuli that give students ample opportunity to discuss chemical concepts. To develop the method, a cyclical research design was adopted. Six groups of high school students participated. The discussions were videotaped and discussed within the team of researchers. The results are a number of principles for the structure of group discussions, for the role of the host, the tasks presented to the participants and the analysis of the videotaped discussions. The principles are illustrated using examples from the discussions. It emerged that students are ready to talk about chemical problems. In the discussions they focused on their interests in a particular field. The group discussion is an open, dynamic and self organising process. Further research can show whether this method also works in other situations. Researchers are encouraged to transfer our principles and guidelines to new topics and to continue refining them. It is also suggested to use group discussions in teacher training. [*Chem. Educ. Res. Pract.*, 2004, *5*, 265-280]

KEYWORDS: *students' concepts in chemistry; group discussions; structure of group discussions; role of the host; ethical concerns; chemical equilibrium*

INTRODUCTION

Constructivism has become a common outlook among science educators. The constructivist framework focuses research on 'conceptual understanding' (Pines & West, 1986). The idea of conceptual understanding itself goes back to cognitive theories of learning. According to these theories knowledge is acquired and stored in the form of concepts (see e.g. Edelmann, 1986). A concept can be a category of similar phenomena sharing certain attributes (e.g. the concept 'oxidation' involves all oxidation reactions). A concept can also include a category plus an explanation or theory of the phenomena subsumed in the category (e.g. 'oxidation' can be explained by electron transfer between particles). There are cases in which different theories exist for a certain concept, e.g. 'oxidation ' can be explained as a transfer of oxygen or a transfer of electrons. A concept can also mean a strategy for solving problems. Each individual builds their own system of concepts, which is coined by personal experience and individual likes and dislikes. In chemistry, just as in any scientific discipline, concepts are constructed according to scientific criteria. It is also important that such concepts have to be accepted by consensus within the scientific community. This marks an important difference between individuals' concepts and scientific concepts. The term 'concept', however, includes both.

An analysis of how the terminology of theories of learning merged into science education is given by Gilbert and Watts (1983). There are a number of terms which describe conflicts between individuals' concepts and scientific concepts: for example 'misconceptions', 'alternative frameworks' and 'alternative conceptions'. Schmidt (1997) makes a distinction between mere errors and alternative concepts. The term "alternative concepts" only applies when students have plausible reasons for their assumptions. Consequently, not all "mistakes" students make are relevant for research. Selley (1997) points out the importance of research that identifies alternative concepts "which emerge from a short but sufficient period of 'personal musings' and discussion….for only then will we be assured of their pedagogical validity". In other words: in contrast to mere errors, alternative concepts are more stable because they "survive" a certain amount of reflection and discussion. For the purpose of this article we will use the term 'concept' (the term 'conception' is used synonymously in the literature) as it refers to any idea a student can hold, regardless of whether it is in conflict or in harmony with the current scientific view. Also, unintended value judgements can be avoided that way.

BACKGROUND

Learning chemistry, i.e. acquiring and changing chemical concepts, is a complex process. Investigating these processes is a complex task. A considerable amount of research has been conducted to study students' concepts in chemistry. Previous work describing the methods used in chemistry education research in this field was reviewed by Griffiths (1994) and Schmidt (1997). Many other articles have been published since. It seems to be a trend in research to look at students' concepts in a detailed and reflective way (White, 1997). Eybe and Schmidt (2001) discussed quality criteria in chemistry education research and how they are met in published papers.

In research into students' concepts in chemistry written tests and interviews play an important role. Usually, written tests (multiple-choice and free response questions) are given to a **larger** population of students. Interviews have been used to study the concepts of a **smaller** number of students and conducted with one, two or three interviewees at a time (see for example Kvale, 1996).

Schmidt (1994) used written tests to investigate students` strategies for solving stoichiometric problems. In three other studies written tests were used to identify and describe the problems students have with the concept of neutralization (Schmidt, 1991), the concept of isomerism (Schmidt, 1992), and the concept of conjugation (Schmidt, 1995). Another study based on written tests was designed to map out students` problems naming oxo salts following a given formula (Schmidt, 2000). In some of these studies groups of students were also interviewed as a means to validate the results from written tests (Schmidt, 1991, 1992, 1994, 1995, 1997). The interviews were videotaped and transcribed for analysis.

To find out about students' understanding of the concept of burning, BouJaoude (1991) used the interview-about-events technique. Students were shown experiments like burning a candle, lighting an alcohol burner, and so forth. The interviewees were then asked questions about the change in weight when things burn, the role of oxygen etc… Griffiths and Preston (1992) conducted interviews to examine students' understanding of atoms and molecules. The interview guide was pretested in pilot studies with smaller samples. Garnett and Treagust (1992) used interviews to identify students' concepts in electrochemistry. First a sequence of propositions thought necessary for understanding the concepts was set up and evaluated by teachers. These formed the basis to develop the interview guide. In a longitudinal study based on interviews Johnson researched the development of students' understanding of boiling water (Johnson, 1998) and their concepts of a substance (Johnson, 2000). Taber interviewed students to reveal their ideas about atoms and bonding (Taber, 2001, 2003). Some interviews were conducted with only one student during and after some time he or she had learned about that topic (Taber, 2003).

Gilbert and Pope (1986) conducted small group discussions built around a stimulus situation. Students were arranged into groups of two or three. In these discussions, students had the opportunity to hypothesise about the stimuli they were given and to challenge each others' conceptions.

Schmidt, Baumgärtner and Eybe (2003) conducted a combination of written tests and interviews to study students' understanding of the concept of isotopes. Students were first required to respond to multiple choice questions. The information gathered was then used to design the interview guide. The same method was applied to probe students' understanding of the oxidation concept (Schmidt & Volke, 2003).

Van Driel, de Vos, Verloop, and Dekkers (1998) studied students' reasoning about the concept of chemical equilibrium when this topic was introduced in a laboratory course. The data collected consisted mainly of audiotapes of classroom situations and students' written responses to questionnaires.

AIM

The situation in which research is carried out can strongly influence the outcome. A variety of research methods is necessary to provide relevant research results. In the studies reviewed above the researcher determines the questions that are asked and – in interviews – more or less the course of the conversation. The present paper explores the possibility of conducting discussions with entire chemistry classes in such a way that students are given a stronger role: they are to decide which issues to discuss and they are expected to challenge each others' concepts. At the same time the researcher's influence should become as little as possible. We found that 'discussion' was a good way to achieve our aims and that 'group discussion' was the appropriate term. Samples of group discussions were conducted in order to develop

- guidelines for their structure;
- guidelines for the role of the host;
- stimuli that give students ample opportunity to discuss chemical concepts;
- guidelines for the analysis of the discussions, and to describe samples of group discussions.

METHOD

Design

Cyclical research designs (Figure 1) are frequently used when research methods have to be adapted to new situations (see for example Mayring, 1996).

First, our *initial understanding* of the way we intended the group discussions to be conducted was explicated:

- the influence of the researcher should be kept to a minimum;
- the conversation should focus on a topic in chemistry;

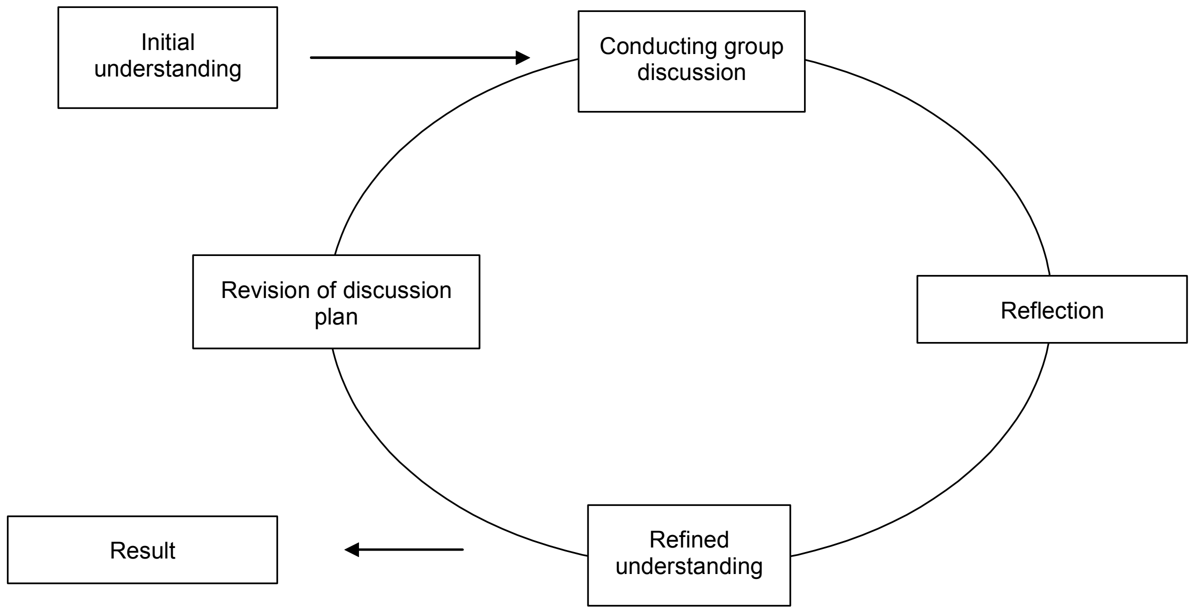

FIGURE 1: *The cyclical research design.*

- the conversation should focus on chemical concepts;
- students should have as much opportunity as possible to discuss any aspects of a topic they find relevant and to determine their own ways of discussing them;
- the discussion should be beneficial to all individuals involved. Any potential damage to the students, the teacher and the researchers should be kept to a minimum.

An initial discussion plan was drawn up.

For *conducting group discussions* chemistry courses were invited via their teachers. The courses were either basic courses (three chemistry lessons per week) or advanced courses (five to six chemistry lessons per week). They came from German grammar schools (11^{th} and 12^{th} form). Six groups of students participated. The average group size was about 15 students. The discussions were organised as part of a day trip to the university that gave students the opportunity to get to know the campus and some of the departments. 45 to 90 minutes (depending on the topic to be discussed) were usually allotted for the discussion. The event took place in a special seminar room equipped with microphones and three video cameras installed behind windows. The discussion was monitored from the gallery by at least one other member of our research group.

Three researchers conducted group discussions. Each researcher was working on a certain topic (electrochemistry, chemical equilibrium and chemical nomenclature). Two of them were PhD students with limited teaching experience and one of them was a university lecturer who had many years' teaching experience in secondary school chemistry and at university.

After each discussion, meetings of the research group were held for *reflection*. Whenever possible, there were also meetings with the teachers and some of the students involved. The researcher who hosted the group discussion would report on their experiences. New ideas for conducting discussions were collected. Passages of the discussion were reviewed by the research group to estimate whether the contents seemed worthwhile for analysis. Notes were taken during these meetings. A *refined understanding* of how to conduct group discussions in better harmony with our initial principles developed from the meetings.

This process often led to new ideas for the creative process of writing and *revising discussion plans* and finally to the research results presented here.

Plans for group discussions were developed to suit different chemical topics and different group characteristics (group size, students' previous knowledge of the topic).

Data collection and analysis

Six group discussions were conducted in the main part of the investigation. The data consisted of the video material that was recorded during the group discussions, protocols and summaries of the meta-discussions within the research group and with students and teachers. Hence, we did not rely solely on the analysis of videotapes. As far as possible we validated each step in the video analysis in a process of triangulation with the data from the other sources (e.g. protocols of meta-discussions). That means that different perspectives were considered if possible. For example, a situation from one of the videos could be triangulated with comments students made after the filming had finished. The consequences for the validity of the results will be described in the discussion section.

The data analysis was carried out in two phases: during the first phase we concentrated on the method itself in order to develop principles and structures such as guidelines for the host, discussion plans, tasks and technical details. As the research process continued, these findings were validated and refined. We also developed guidelines for the second phase, namely the analysis of the actual contents of the group discussions.

RESULTS

This section presents our final decisions on various aspects of group discussions. Typical situations are outlined, a detailed description of an exemplary case included in the Appendix.

Structure of the group discussions

The discussions conducted had the following structural elements:

- *Warming up*: Conversation and small talk to become acquainted and to get used to talking in a new situation.
- *Briefing*: The participants get to know certain information about the purpose of the discussion, the duration, technical details etc. that enables them to decide freely whether they want to participate.
- *Presentation of the task*: The task is presented, commented on if necessary and any questions as to the task are answered.
- *Planning the discussion*: The participants decide how they wish to proceed. The help of the host may be necessary here.
- *Discussion*: Free discussion within the group. The host only intervenes if any of the discussion guidelines is violated or if the group seems to need help in structuring the discussion.
- *Summaries*: From time to time the participants are asked to summarise certain points. This brings more clarity to the discussion and more validity to the data.
- *Additional stimuli*: The host introduces new stimuli, but only if the discussion seems to be stuck without new input.
- *Final summary: solution of the task*: As the group has been confronted with a task, the natural endpoint of the discussion is the successful solution of the task.

- *Meta-discussion*: Discussion about the discussion in which crucial points can be reviewed. This gives students the chance to clarify misunderstandings.
- *Debriefing*: Closing the session and giving information about what will happen to the data.
- *Reflection with teacher*: As there is no contact between the teacher and the host as well as the students, there has to be an opportunity to exchange comments and to discuss each other's impressions of the discussion.

The structure of the discussions was seldom so rigid that there were clear lines between the aforementioned elements. Also, elements like planning the discussion, discussion and summaries would appear several times depending on the course of the discussion. The amount of additional stimuli also varied, depending on whether the participants had already been introduced to the topic to be discussed. The point at which the cameras are turned on, however, is an important marker in the plan. Everything that needs to be said to achieve informed consent (see below) has to be settled before that point. There should also be some time left after the cameras have been turned off. Participants might have comments or questions which they do not want to be recorded.

The discussion plan used by the researcher did not (apart from the task) consist of full sentences and questions the host would read from a card. It was rather a collection of information that had to be passed on to the group and some possible questions for the different phases. Also, a time schedule was drawn up on the plan.

Ethical concerns

When the students were invited to participate in an discussion they were informed about the aims of our research as well as the technical details (duration, presence of cameras) of the discussion. The students were free not to participate. We attempted to achieve 'informed consent' (Brickhouse, 1992; Tobin, 1992). Students were also informed that their teacher would be sitting in the editing room watching the discussion from there, accompanied by a member of the research group. It was made clear to the students and the teacher that the discussion would be an activity that was not part of the curriculum. Hence, we asked the teacher not to use any impressions from the discussion for assessment. After the discussion, we tried to make sure that it did not cause a dissonance between the teacher and the students. Both sides were invited to reflect upon the discussion.

Teachers were sometimes surprised, even dismayed, at the open display of incorrect ideas because they feel responsible for their students achievements. We tried to counterbalance that in two ways. Firstly, the researcher accompanying the teacher would make positive comments about the students' reasoning. These were heartfelt comments as research has shown how intelligent and logical students' incorrect ideas can be. Secondly, the host of the discussion made sure that towards the end of the session there would be a positive outcome. Any misunderstandings left were clarified as far as possible with additional intervention from the host where necessary.

The fact that we worked with groups of students also had a positive effect on the protection of individuals. It was decided not to call upon students as we wanted any contribution to the discussion to be voluntary. On the other hand, the host did ask questions and made requests to individual students as part of the conversation. Any refusal on the side of the students was respected by the host and there would be no follow-up questions to press the point. More details about the role of the host will be given later.

The group discussions conducted strongly relied on students' willingness to think, to be active in the discussions and to co-operate with the researchers and each other. We found all groups to have this competence.

Role of the host

We have drawn up a set of guidelines for hosting a group discussion. The guidelines are commented and illustrated with some examples from actual discussions. The examples taken from our data show how the principles were derived from the data.

Talk as little as possible and do not participate in the discussion

This guideline, quite ironically, implies that the host should not ask too many questions. It is the host's job to keep the discussion going and, if necessary, to help the participants structure their conversation. There should be no participation beyond that. This rule is very difficult to observe as the host is emotionally involved in the situation. There are mechanisms which draw the host into the discussion.

> Example: after a question was posed by the students the host repeated this question. A student asked the host: "Can you explain the question further?" The host had to avoid participation by saying: "Well, it was not my question..." turning the attention back to the student who had posed the question in the first place.

Rely on the students to be active during the discussion

There is a lot of pressure on the host. There are cameras, microphones and people watching from the editing room. The host feels responsible for making an interesting, even entertaining video film. That, however, is not the aim of the research. The students are the ones who are supposed to act. Hence, they need to be given the opportunity to take the initiative. There can be lengthy passages of silence during the discussion that are often hard to bear for the host. The silences are a good means, however, to show the students that it is up to them to do the next step. Also, students often need pauses to think before making a suggestion for further discussion. The host becomes more experienced in distinguishing such pauses from situations where the discussion needs a new stimulus.

> Example: We noticed that the teacher watching from the editing room sometimes feels awkward about the pauses. One teacher commented something like: Oh, I can't sit still - the host is incredibly patient. Hence, it is also important that the use of pauses has to be explained to the teacher.

Make sure that a good atmosphere for discussion is maintained

The discussion should take place in a friendly, non-threatening atmosphere. The host should make sure that any disagreements are handled matter-of fact and not on a personal level. No student should feel embarrassed about their contribution. The discussion is designed to make misunderstandings apparent. When it becomes obvious that a student has been on the wrong track, the host can praise the student for making a contribution that was convincing enough to be discussed for a period of time before it was revealed to be incorrect. It is also important, that the students succeed in the end so that there is no frustration after the session.

> Example: A teacher who had participated with a group before remarked: "After our last discussion my students were very motivated because they got so much praise for their mistakes."

Make students work together as a group

In order to protect the individual and to create a good atmosphere, students were asked to co-operate. Tasks were never assigned to individual students, they were always presented to the group as a whole. The host intervened when too much attention focused on a single student.

> Example: A student struggled to draw a diagram of something that was being discussed on the blackboard. He found that he could not really do it and looked defeated in front of the whole group (and, not to forget, three video cameras). The host pointed out that the task of drawing the graph was the groups' task and not the student's task and suggested that the student be the chair for the discussion on what to draw in the diagram. The student cheerfully adopted his new role and addressed the group: "Go on then, you tell me what to draw in here."

Praise correct and incorrect statements

Any contribution to the discussion is valuable. In school lessons the focus is often on whether a contribution is correct or incorrect. In order to get insights into students' concepts it is important that all views that are held within a group can be expressed without judgement.

Encourage students to disagree.

As mentioned above, students are asked to co-operate as a group. It is thus necessary to reach a consensus on which ideas the group regards as correct and which way of tackling a problem would be best. To some students it can be a new experience that learning chemistry can be about different ideas and opinions rather than mere scientific facts.

Explain your role as the host

The guidelines show that the role of the host is quite different to that of a teacher. Students were sometimes bewildered at the host's behaviour. The fact that the host does not give clues as to which views are correct can lead to confusion and uncertainty on the side of the students. We found that the role of the host cannot be fully explained before the discussion. That would make the briefing much too long. Consequently, the strange behaviour of the host sometimes has to be explained as it occurs.

Group size

The average group size was approx. 15 students. However, we also conducted discussions with a mere two students (which of course reduces the multiplicity of opinions). In groups of less than ten students, the atmosphere was usually such that all participants were active. In larger groups, some of the students tended to hide or perhaps did not get the opportunity to contribute anything new. We had one group of 28 students which we handled in a different way: the large group was divided into two small groups of 14 students who started a discussion on the same topic (we used Task 2) in separate rooms. The two hosts scheduled a time (about 30 minutes into the discussion) when one of the small groups would join the other half. Before that, both groups took 5 minutes to write a summary of the terms they had been discussing and a list of questions that had remained open during the discussion. The two groups then exchanged summaries and continued the discussion together.

The tasks

General considerations

The tasks that were used to initiate the discussions were developed in a creative process. Nevertheless, there was a certain systematicy to that process. Usually, different ideas were collected and discussed with the researcher who was going to be the host and other members of our research group. It was important that the task would fit in with the research questions and the principles for conducting discussions (see above, e.g. ethical issues).
The following characteristics seemed important:

- The task has to be open on the one hand and set a certain frame on the other hand, so that the discussion remained focused on the chemical content of interest.
- It should offer possibilities to have a controversial discussion. Some tasks made use of possible cognitive conflicts.
- The students should have the feeling that they can come to grips with the task by themselves (i.e. as a group). Hence, the degree of difficulty had to be chosen carefully.
- The task should motivate students to think. It should be interesting and motivating to the students.
- The task should draw students' attention to chemical concepts. Calculations and complex algorithms that can only be done in writing should be avoided.
- The task should include a way of visualising the concepts to be discussed.
- The host should feel comfortable with the task

Examples

Here are some examples of tasks that were used in the study:

Task 1: Chemical equilibrium

Imagine the following situation:
A fellow student from the tenth form wants your help. He has to take a written exam tomorrow. The topic is *Chemical Equilibrium*.
He wants to prepare a crib that explains briefly what chemical equilibrium is. The crib should explain this as accurately as possible using only few and simple terms.
Task 1 was simply presented on a transparency illustrated with a cartoon picture showing a student thinking hard. Afterwards, various chemical terms needed for the crib were suggested by the participants and written down in large print on A4 sheets of paper. These were collected on the blackboard using sticky tape. Next, the terms were discussed one by one by the participants as to what the student needs to know about them.
Typical characteristics of this task are the high degree of openness and simplicity. When the discussion became elevated at some points, the students, bearing the task in mind, decided by themselves to go back to more basic concepts.

Task 2: Chemical equilibrium

Consider a container filled with N_2 and H_2. Please complete the reaction equation:
Container 1

$N_2 + H_2 \rightarrow$

> Now consider another container filled with NH_3 under the same conditions. Please complete the reaction equation:
>
> Container 2
>
> $NH_3 \rightarrow$

Task 2 was presented stepwise on the blackboard. What triggers the discussion is not the completion of the equations (students immediately knew the correct solution), but the apparent contradiction between the equations. During the discussion the students have to realise that both reactions take place in both containers as the forward and the reverse reaction of a chemical equilibrium. This task was designed for a group who had not been introduced to the topic.

Task 3: Electrochemistry

> On the blackboard you can see a schematic drawing of an electrochemical cell. Some of you have big cards with electrochemical terms on them. The task for the group is to complete the drawing with the terms on the cards. Those of you who have cards get the role of a group representative in charge of the term on the card. The job of the group representative is not to solve the task, but to collect the group's ideas and to finally fill in the term where the group has decided it should go.

This task was presented orally after the cards had been distributed. The procedure is easy to follow for the students: the first one holding a card goes to the blackboard and waits for the group's decision as to where to fill in the term. The host can remain passive during that time.

Task 4: Chemical nomenclature

> On the desk at the front you can see sheets of paper with chemical formulas written on them.
> (1) Find the names of the chemical compounds according to the formulas.
> (2) Think of a classification scheme for the formulas, sort the sheets accordingly and stick them to the board.

This task is suitable for shorter discussion sessions (approx. 45 minutes). It was used in an investigation of students' problems with naming oxo salts following a given formula. The results have already been published (Schmidt 2000).

Data analysis and possible outcomes

For the analysis of the videotapes, we used copies which had the time code in a corner of the screen. This allows swift access to any passage of the tape, even when they are used on different videotape recorders.

The data analysis of the films has to be focused on certain aspects from the beginning. These aspects, of course, strongly depend on the research questions. Any piece of film in which a group interacts can contain an almost infinite amount of data. There is spoken language, body language, facial expressions, gestures, different roles and functions within the group etc. In our research the focus is on students' concepts in chemistry. It was, therefore, decided to concentrate on the chemical content of the conversation. Hence, our analysis was guided by categories of chemical contents. These categories could be taken from the video material without much difficulty as, due to the tasks, the conversation is largely structured along chemical terms anyway. For these categories protocols were written. These protocols were no verbatim transcripts in the 'classical' sense - they were already condensed and focused on meaning. However, they did contain passages of verbatim transcription. This led to an immense reduction of the data. However, we frequently went back to the original material to review the richness of the situation. Verbatim transcripts were used as examples and to illustrate the arguments in research reports.

The aforementioned reduction of data was only possible because, due to the discussion plans, the material had certain characteristics. Some uncertainty as to the meanings of the conversation could be avoided as the group discussions have a built-in method of validation. The students pose questions to one another to clarify meanings. This often makes the interpretation a straightforward task.

Another aspect that guided the interpretation of the data was the importance given to certain topics by the students. That means that because the students were free to decide what they found worthy of discussion, they quickly moved the conversation away from topics they did not find important in a particular situation. Problems that were discussed thoroughly were often such that incorrect and correct ideas were equally convincing to parts of the group. In such cases the arguments and counter-arguments are particularly interesting from the point of view of teaching. It becomes apparent what concepts students can hold, what the discrepancies between the concepts are, and how they can be overcome in a discussion or, as in some cases, why they are so persistent that they cannot be overcome in a discussion.

The use of name badges and of video instead of audio recordings made it easier to follow the speakers and to recognise them even if they were off-camera (the editing could not always be accurate when the discussion moved quickly from speaker to speaker). However, it was not our intention to make lists of all statements and to attribute them to the participants. When we used verbatim transcripts the sequence of speakers would of course be maintained.

To illustrate actual research outcomes from group discussions an example from a small study about chemical equilibrium using Task 2 is presented. The question raised by Task 2 is: would the students accept that when nitrogen, hydrogen, and ammonia are at equilibrium, ammonia is formed and decomposed at the same time? Students' initial reaction was that a decomposition of ammonia was not possible. Students had a number of objections one of which was:

It [ammonia] was formed under these conditions, so it cannot go back.

These objections were discussed for a couple of minutes. Then the host gave an additional stimulus to move the discussion further:

What if I told you that the second reaction is also possible?

The students then engaged in a discussion about the change of concentrations of products and reactants, depicted this as time/concentration graph and got very close to the scientifically accepted idea of the dynamic equilibrium. During a summary phase, the students came back to their initial problem of accepting the reverse reaction at all. They repeated:

Well, we had assumed that it is possible.

After about 50 minutes of conversation, when the group had quite extensively elaborated on their understanding of chemical equilibrium, they came back to the initial problem once again. This time, however the statement "We had assumed it is possible" was challenged by a student:

Yes, but it is nonsense, I still don't believe it.

Quite possibly, the students had gone through much of the discussion just as a favour to the host. The crucial point, however, had apparently not been settled yet. This outcome can have implications for the classroom. The same problem could occur in teaching: students handle new information given by the teacher without really accepting it.

DISCUSSION

The aforementioned example from the field of chemical equilibrium shows what group discussions can contribute to the research process. The fact that students have difficulties accepting the concept of a reverse reaction has been reported in the literature (van Driel et al., 1998). The group discussion provides a new angle for the investigation of students' concepts. It can be seen, for example, whether – or not - students can overcome a conception when challenged by their peers. Hence, we get an insight into the stability of students' concepts. The research results, therefore, have a high “pedagogical validity”.

The study shows that students are ready to talk about chemical problems. In the discussions they focused on their interests within a particular field. Frequently they even shifted the conversation to aspects we had not been aware of. In that way new research questions were brought into the research process by the students themselves. This could also be seen as a disadvantage. There were situations where we would have liked to know more about individual students' thinking. The focus on students' interests would be difficult to achieve when preparing one-to-one discussions. The group discussion is a more open, dynamic and self-organising process.

In group discussions the main focus is on the students, but in a way the teacher is also under investigation. The teachers observed the discussions together with a researcher. Their reactions, observed by the researcher, can be seen as part of the discussion data. We decided against installing a tape recorder or even a video camera to observe the teacher more closely. The teachers reacted to a situation in which they had no control. This presented an ethical dilemma to us. Being confronted with the apparent outcomes of their teaching, especially looking on as their students make 'terrible mistakes', the teachers might find themselves receiving treatment without their consent. Removing the teacher from the situation entirely does not solve the problem either, because not knowing how the students performed and what light this shed on their teaching equally affects the relationship between the teacher, the students and the researchers.

Our analysis of the videotapes as well as the discussions among the researchers revealed that there was sometimes a discrepancy between the impressions the host gained in the real situation on the one hand and the video film on the other hand. Despite the fact that three cameras were used, the film only provides a keyhole perspective of the actual situation, which is of course a limitation to the data material. Our conclusion was to enrich the data by including the hosts' perspective in the analysis where necessary. This could be seen as triangulation of data from different sources.

As for the validity of our principles, we used two means. Firstly, as just mentioned, data from different sources were used to avoid biased interpretation. Secondly, the results were evaluated by members of the research group and, as far as possible, by the teachers and students involved in the research (communicative validity).

IMPLICATIONS FOR RESEACH AND TEACHING

We have used group discussions as a tool for investigating students' concepts from various chemical topics. This paper should encourage other researchers to transfer the principles and guidelines described to new topics and to continue refining them. In future research, interesting results may be found using the new method to identify students' understanding of the relationship between structure and properties of compounds (Schmidt, 1996). Group discussions are based on stimuli needed to initiate conversations between the participants. It may also be fruitful, too, to study the role of other tasks, for example (small scale) experiments, in group discussions. Finally, it would be interesting to use our tasks for discussion with other groups.

Hosting a group discussion can be a frustrating and disturbing experience if something goes wrong, especially because everything is caught on camera. Planning and reflection should, therefore, be carried out by more than one person, preferably in a team of researchers with similar interests and in an atmosphere of mutual trust.

We had excellent video recording facilities available to perform the group discussions. Certainly, group discussions could also be recorded audio only, even if the data analysis became more cumbersome.

Group discussions in the form presented in this paper might not be suitable for direct use in teaching. It would be difficult for teachers to create an appropriate situation and probably too time-consuming to analyse the data. Teacher-training courses might be the right place to transfer this research into practise. Prospective teachers could gather valuable experience if they conducted group discussions as part of their studies. There is much to be gained in research by talking with and listening to students.

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APPENDIX 1: AN EXEMPLARY CASE

In order to describe the situation in which the principles and elements mentioned in the 'results' section work together a 'fictional' case is presented. The case is fictional in that it did not actually occur as it is written down here, but all the situations described were taken from actual group interviews. It is a report on several group discussions condensed into one. The topic of the discussions was 'chemical equilibrium' and the task that was used was Task 1 (as described above).

> After preparing the studio room, the host goes to meet the group in the foyer of the chemistry building where he meets his fellow researcher who will later join the teacher in the editing room. The teacher and a handful of students are the first to arrive. Apparently, they have had a presentation in another chemistry department which was quite interesting for the teacher and mildly so for the students.
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> While the students are gathering, the host takes the teacher aside and explains what the situation will be like in the studio. The host points out that the group discussion is supposed to be a situation in which students will be asked to talk freely and that an assessment of students is clearly not the purpose. The teacher is willing to co-operate in every possible way and says that it had not been his intention anyway. They both agree that telling the students they are not being assessed it might help to create a good atmosphere for the discussion.

The teacher calls his students around and the host introduces himself. The tone is rather informal and students are curious what the next item on their programme is going to be. The host gives a brief description of the research project he is involved in. He asks students whether they would like to help and participate in the project. He also says that anyone who does not want to be filmed or refuses to participate for some other reason is free to leave, but nobody does. The students are informed that the video material shot during the discussion will only be accessible within the research group and is otherwise confidential. The host confirms that the discussion will last about 90 minutes, as scheduled in the programme. He points out that the teacher will be watching the discussion from another room, but with no chance to intervene. The students seem glad to hear that testing or assessment is clearly not the purpose of the discussion and that the teacher has promised not to include today's impressions in students' marks.

The first group activity then is to make name badges. The host passes felt pens and sticky crêpe tape around and the students write down their names; some of them use nicknames. After five minutes of cheerful activity, the students, the host, the other researcher and the teacher head for the studio.

During the ten-minute walk, the host has the opportunity to chat with some of the students. For example, he asks what other courses, beside chemistry, they have chosen and learns that some of them have pedagogics. Other topics include students' questions on what it is like to be a researcher and the quality of the cuisine in the cafeteria. Some students also mention that they have some reservations about the oncoming discussion. They feel that chemistry is their weak subject and are not sure whether they will be able to contribute much. The host tries to encourage them.

In the studio, some of the students seem a little intimidated by the setting. Some seem excited to be part of something so important that it is filmed by three cameras. Meanwhile, the teacher is equally impressed by the TV electronics in the editing room.

The cameras begin to record and the host presents Task 1 on a transparency and comments briefly. The host mentions that he has heard that some of the students have pedagogics courses, so the group is perfect for the task. The task is received with friendly comments by the students, and the atmosphere remains rather light-hearted. This phase of presenting the task lasts about 2-3 minutes.

The next 20 minutes (approximately) are then used for collecting terms on A4 cards. The students soon gain confidence despite the cameras, and come up with a lot of ideas, and there is a lot of activity in the group from writing cards and sticking them on the blackboard. The host points out that, for the moment, all terms are accepted and that the distinction between important and less important terms can be made later in the discussion. Some students already try to give longer explanations rather than just singular terms, but the explanations are also postponed for later.

The students decide on the first term to be discussed. The host takes the card from the blackboard and sticks it to a table closer to the group. A student starts off by giving a short definition of the term. The group finds it necessary to explain it further and to use examples. There are phases in which the students discuss among themselves, pose questions to one another and show agreement or disagreement. At points where the conversation seems stuck or has come to a natural endpoint, the researcher intervenes by making the students summarise their arguments or by asking them whether they think the present point has been settled, and collecting or making suggestions for further discussion (for example deciding on the next term to be discussed). He also tries a few follow-up questions on interesting points, but the students seem intimidated by that. At some points the host intervenes. On a few occasions, he notices aggressive undertones between two students and helps to settle the point peacefully. At another occasion, one of the students becomes rather dominant and seems to be accepted as expert by the group. The host points out that it has not been decided whether the 'expert's' statements are really correct and encourages other students to express their opinion.

In the editing room, the teacher is going through a series of mixed emotions. First, he seems relieved that the students participate in the discussion at all. He was not quite sure about some of them, who, much to his surprise, are now even more active than in ordinary lessons. As students make some incorrect statements and some pauses, where they are unsure how to continue, the teacher seems uneasy and sometimes even embarrassed. The researcher who is with him engages in a discussion with him. He points out that, from the point of view of research, these 'mistakes' are a normal part of the learning process and that the students are doing very well. After all, the students have many constructive and intelligent ideas in the discussion. The teacher has more questions about the purpose of the research, and so the discussion in the editing room continues.

Only minutes before the 90 minute time limit the students have discussed the major terms. They are willing to go on, but the host does not allow any new topics to be brought up. All the cards that have been discussed have been gathered on the part of the blackboard reserved for the crib. The host briefly reviews some of the terms. He explains that he is now going to drop his role of the 'neutral' host and will be ready to answer any questions that are left. First he clarifies a few difficulties he noticed during the discussion, goes back to one of the students' examples and rectifies some of the statements from before. During this phase of the conversation, the students are still highly attentive, even after almost 90 minutes of discussion, and are eager to know the solutions to problems they had been struggling with.

The students are invited to comment on the discussion. The response is very positive. They say, however, that they sometimes found it hard to help the tenth-grader as they had so little information about him. Two students noticed the fact that chemical equilibrium is not part of the curriculum for grade ten. They come up with the point after the session has been closed; apparently they did not want to criticise too much in front of the whole group. The host says that they are quite right and thanks them for having participated so actively regardless.

The students go to meet their teacher and the other researcher in the editing room. The tape is rewound and they can watch a little excerpt from the discussion. There is laughter and the odd "Oh, no!" A copy of the tape will later be available for the class.

On the way to the cafeteria, the students and their teacher talk about a few points from the discussion. The host also has the chance to exchange a few words with the teacher. He praises the students for their stamina and so much valuable contribution to the discussion as well as the whole research project. The teacher says that he has enjoyed the experience of looking at his students from a different angle. He wishes the host good luck with the data analysis.

Back in the chemistry department, the research group has a meeting about this morning's group discussion. The host and the researcher who accompanied the teacher report on their experiences. Some points from the discussion are reflected upon, and new ideas for the next group discussion are collected. The host also gets a lot of feedback from the researcher who was watching from the editing room.

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