COMMUNICATION AND LEARNING IN SCIENCE LESSONS

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Background
In this paper we present a study on the role of communication between teacher and students and between students in science lab work. One goal of the study is to investigate how improved communication contributes to a better understanding of science phenomena. The processes of learning are studied in an exploratory study performed in science classrooms.

This study is carried out from a combination of individual and sociocultural view of learning as it is described by Leach and Scott (2003). According to this view learning involves both individual construction of knowledge and social interaction between individuals and that understanding emanates from social interaction, and will be interpreted and then made clear for the learner. Leach and Scott build upon Vygotsky’s view of development and learning that higher mental processes in the individual derive from social life.

Vygotsky (1996) argued that there is a possibility for individuals to increase their learning ability by cooperating with others. He described this possibility by using the concept of the zone of proximal development, ZPD. At a certain level of development an individual can cooperate with others in special situations. With new knowledge acquired he/she can cooperate in more advanced situations in the future. The long time aim of education according to Bruner (1960) is not only the progress for the moment but the ability to more progress in the future.

Interaction between students in science laboratory lessons is dependent on the language the students use during their conversation. Language and conversation are according to Lemke (1990) the most important mechanism we have for developing, testing and communicating knowledge. He stated that lab work offers unique possibilities. Students talk science with each other to guide themselves through prescribed experimental procedures, to decide what to do when something seems to have gone wrong, and to write notes on what they have done. Säljö and Wyndhamn (2002) claimed that the pedagogical conversation is the most important function we have to help the students to become familiar with science. White (1996) meant that most critics of lab work in science focus on that students follow strict instructions without thinking about the purpose of how the ‘experiments’ relates to other information they have learnt.

Practical work in science education
Many science teachers regard hands-on experiments as the heart of science teaching. Hodson (1993) discussed if students will be motivated by practical work, if it helps them to understand science better, and if the “scientific attitudes” will be fostered by practical work. Watson (1995) found that students gave descriptions and not explanations when explaining combustion. Most children cannot use experiences from practical work to modify their concepts of combustion. He discussed if comparing different models of explanations could complete the practical work. In an earlier research project, Eskilsson (1999) noticed that the practical problem solving challenged most of the students and led to lots of discussions. In some situations students in a lab group concentrated on their prior experiences. They were discussing and asking each other questions during their work. Other students tested ideas without discussing them with others in their group. Sjøberg (2000) discussed the aim of practical work in school science and one of
his conclusions was that it was uncertain if practical work helped students to learn scientific concepts and theories. Leach and Scott (2003) showed that introducing students to new science concepts is a subtle process, which is enacted through teacher and student talk and takes place over an extended time line. They also made a comment to the role of practical work in science learning by suggesting that teaching might involve students in practical activities, each of which has a clear purpose. Taken together these different kinds of teacher interventions and the ongoing interactions between teacher and students constitute a teaching and learning 'performance' on the intermental plane of the classroom.

Millar et al (2002) mapped the varieties of practical work and presented some implications for teaching and research. They compared teacher’s objectivities, what students actually do and learn. They meant that such mapping could be used in studies of the aims and the effectiveness of practical work.

Jenkins (1999) meant that working with concrete materiel in the lab and outdoors gives students sense of the phenomena that science tries to understand and explain. He meant that some practical activity helps students to understand the nature of science and how hard it is to learn about the nature. One problem is that students look upon work in laboratory as doing experiments. Laboratory work should be more planning and realization of an investigation, which involves more imagination, creativity, technology, and cooperation that could end in success or failure. The students learn to use science methods and concepts, develop their thinking and arguing. According to White (1996) there is a risk that students don’t see clear links between theoretical schoolwork and practical work. Many studies have shown positive results from using a clear strategy for the design of the laboratory lesson attached to a theoretical presentation. The goal for practical work according to Lazarovitz & Tamir (1994) could be to support meaningful learning by completing theories and some application of the theories and to stimulate development of analytic and critical ability.

Hofstein (2004) summarized new information based on scholarly research about laboratory work. He meant that school laboratory activities have special potential as media for learning. The teachers need knowledge and need to enable students to interact intellectually and physically – both in hands-on work and minds-on reflection. Teachers need to learn more about what their students are thinking and learning. Nakhleh, Polles, and Malina (2002) explored how the concept of distributed cognition could be a fruitful framework for investigating students’ learning in a laboratory environment. Distributed cognition is a hybrid of studying all aspects of cognition. They argued that worthwhile knowledge is not only what resides in individuals’ minds. Knowledge can be distributed over the environment and the individuals and the tools that interact in that environment. They meant that research within the distributed cognition framework would focus on the whole laboratory environment. They found that studying students’ learning in the laboratory with the distributed cognition framework contains many different focuses, e.g.

• The role of the lab instruments and other materiel used
• Interactions between the group members
• The students’ goals for the lesson
• Alternative assessments.
From the above theoretical perspective this study of concrete situations during students’ lab work is set up. Interactions based on Ann L. Brown’s (1992) reciprocal teaching strategy in her research project “Fostering Communities of Learners” are used. The reciprocal teaching groups are designed to help students to monitor their comprehension. Brown discussed why students not are aware of their learning strategies. She claimed that students need to learn how to learn and she focused a/ remembering and b/ monitoring. Brown used Bruner’s (1966) four concepts for good learning environments: agency, reflection, collaboration and culture. Brown et al (1996) stated that FCL was more and more influenced by Vygotskian theories. Mercer (1996) too meant that students have to learn more about collaboration. Favourable conditions for fruitful discussions involve that teachers must stimulate students to talk to each other when solving a problem.

**Research questions**
The research questions of this study are:
- What is the role of interaction between teacher and students and between students during lab work?
- How does communication during lab work contribute to science learning?

**Methods and sample**
This study is carried out in two classes with fifty students 14-15 years of age. The chosen classes have teachers who have a special interest in developing their teaching in chemistry. The study consists of two instructional units and interviews with students and teachers. In this paper we only present the 2nd unit.

The first teaching unit provides a background for the planning of the interventions in the 2nd unit based on Brown’s research strategy “Fostering Communities of Learners”. The interventions involve students working in groups of three, where one of them is
chairperson, one is secretary, and one prepares a report to another group. All the students in a group take part in the practical work. Camcorders supplemented with tape-recorders are used to document the activities because it enables studies of the complex classroom environment (Hiebert, 2003). The video and tape recordings are used to analyse the role of interactions and how these interactions contribute to students' learning.

The topics for the lab work studied are foodstuff chemistry in class A. Half of the groups experiment with coagulating proteins. The other half of the groups in class A experiment with fat. The students investigate if fat is soluble in water, acetone and petrol. They also compare what happens with drops of water and cooking oil on a filter paper. Then each group experimenting with fat have to tell a group experimenting with proteins what they have done and about their conclusions and vice versa.

The topic studied in class B is about acid-base concepts. The students investigate the pH-value of fruits and other kinds of foodstuff, and the relationship between sour taste and pH-value. They also examine natural pH-indicators and carry out different experiments about the relationship between acids and bases. Some experiments are compulsory for all groups in class B. Then the students in this class can choose different experiments. Also here the students have to report to another group about their experiments.

In the interviews with the students their learning and their view on this way of working are focused. The students are asked to describe the work in the group of three. They also are asked to analyse their learning during the lab work and during the report to another group.

In the interviews with the teachers are discussed what happens during the intervention using video cuts of situations from the lessons like Duit, Fischler, Fischer and Sumfleth (2002). The chosen cuts illustrate interactions during lab work and the reporting to another group and from teachers' discussions with students. The video cuts are used to recall the lessons and to stimulate the teachers' analysis of students' learning, and of the interactions between students, and between themselves and students.

Nakleh et al (2002) argued for a new emphasis in studies of laboratory work. They meant that it is no longer appropriate to assess laboratory work simply by reading laboratory reports or testing individuals in different situations in order to evaluate fact acquisition. Instead we must include assessments of group learning and laboratory practical. As consequence of these arguments Nakleh et al claimed that there are five broad areas of research that would shed some light on the laboratory as a learning environment. Among these areas are studies of interactions within the environment, and studies with focus on the students' perspectives of the lab work. This research project includes these two areas of research together with the teachers' perspectives of the lab work.

Data are acquired from the interviews with students, interviews with teachers on the one hand talking about the intervention, on the other from comments to the video cuts, from the video recordings and tape recordings from the lessons and written notes from students and from us.

Data analysis and findings
The video recordings are used when analysing what happens in the lessons, and the interviews to analyse the students' and the teachers' interpretation of what happens. In
order to investigate the students’ understanding of the science content their discussions in the video recordings, and the transcribed interviews with the students are analysed. Sometimes the video recordings are supplemented by the tape recordings from the different groups. In the interviews the students are asked what they think they have learnt and what they have worked with in the laboratory lessons. Then they are asked to explain what has happened. The interpretation of the reporting to another group focus the discussions between the groups and how the students use science content when explaining the experiments and the conclusions of their experiments. The students also have to describe how the intervention influences their work and their learning.

**Interviews with the students**

The interviews with the students are analyzed from two perspectives:

- our analysis of students’ learning and understanding
- the students’ description of and their views on this way of work in laboratory lessons.

**Class A**

Only a few of the students spontaneously can describe what they learnt in the laboratory lesson four weeks earlier. When asked follow-up questions almost all of them remember what their group has done and they talk about details when they describe the experiments. They use science words and concepts in different extent. Some of them say that the protein coagulates and others use the everyday words that the protein gets stiff. Some students talk about heavy metal, copper sulphate and warmth that can make the protein coagulate. The students experimenting with fat describe dissolving butter and cooking oil in petrol and acetone and how to identify fat in food-stuffs by studying if a drop of it evaporates from a piece of filter paper.

The students think it is important to learn about fat and proteins because it is important to know what is in food and this is especially important for those going in for sports. They also say that they have talked about these things in the school subject home economics.

All students can describe how they gave a report of their laboratory work. They talk about the role-play with one chairman, one secretary and one responsible for the report to another group. About half of the students say that they have prepared themselves especially for the discussion with the other group. They have discussed more than usually and they have been more careful when they wrote down their notes about the work. Some groups have written down main points for the discussions. One group says that they have good discussions with the other group. Another group says that they wanted more time for preparing the discussion with the other group. Almost all students mean that they understand what the other group tells them about their experiments. They also think that the other groups understand what they themselves tell the others.

Many students say that they have learnt to report on the experiments and to discuss what happens in the experiments with other students. They also learn science from the report to the other group. Some students mean that when they only have to do
experiments with fat they can focus these experiments and can make good use of their time. Besides learning science they also brush up their capacity of collaborating.

Some of the students however are critical to the method. The reporting group does not understand what they have done and one student says that they were not prepared enough. Some students are positive to the method but they think they learn better when they do the experiments by themselves.

*Class B*

All students in class B talk about acids and bases that are the subject for this group. About half of them use the main scientific concepts in a proper way. They use concepts like acidity, pH-scale, examples of acids and bases and bases in everyday substances and how to mix water in concentrated acids. Some of them have got the pH-scale wrong and say that acids have “high” pH value.

Many students mean that it is useful to know about these things because there are many acids and bases in everyday products and that you must know about pH-scale and acidification.

One student said “This knowledge will be useful for me in the future”.

Almost all of the students mean that they learn and understand better when they have to give a report of the experiments to another group:

If the others don’t understand you have to explain once more.

I dared to tell about the experiments.

I have to understand what I have to tell others.

You must be bright when you are telling the others.

Only a few groups say that they worked as usual. All the students can describe the role-play with the three roles for the students in a group: chairman, secretary, and the presenter. Some students discuss and evaluate working with the three roles. The role-play makes according to some students, the work more organized. One girl says that the other group listened very closely. All the students appreciate that they sometimes have to choose among different experiments. The students become more focused. Almost all of the students are very positive to the method. Many students say that they like best to present their experiments to another group. One group works together with the presentation and means that is a good method. Many groups mean that students like to have clearer tasks because then they take more responsibility for the work. Students say that they train to present something they have done and they train to listen to a schoolmate’s presentation.

Those few students who are critical talk about time-consuming, you learn more when you do the experiments by yourself. One student is dissatisfied with the presentation from the other group.

In summary the interpretation of the interviews is that most students in the two classes show that they understand and can use the science concepts when describing and talking about the experiments. The students also can describe the new way of working introduced and almost all of them appreciate it, especially the reporting to another group.
The videos

Class A

In many situations from the videos we can see that the boys and girls are very good at telling their classmates about the experiments they have done and their conclusions from the experiments.

The teacher tells the students about what they shall do in the lesson and tells them that half of the groups shall experiment with proteins and the other half with fat and that they shall report to a group that has not done the same experiments as themselves.

The analysis of the videos shows that the teachers interact in different ways with the students during the lab work. This can be illustrated with the following examples.

Example 1: The teacher (T) has listened to the presentation and asks a follow up question:

T: Has the protein coagulated?

P1: When you mix hydrochloric acid in a protein it will coagulate.

T: What has coagulated?

P2: The protein

P3: Milk contains much protein and when it coagulates soured milk will be formed.

T: They use an acid for this.

Many students: Lactic acid

T: Soured milk has sour taste

P3: I do not like sour milk!

P2: (checks with T to see if she has understood) When they produce sour milk they use lactic acid in milk?

T: Yes they put many lactic acid bacteria in the milk.

The teacher discusses their results after the report to the other group. She also deepens their discussion. The discussion is on the students’ initiative.

Example 2: A boy is very eager to tell the girls in the other group about how his group examined if fat is dissolvable in ethanol or acetone. He reads from his notes and the girls ask him when they do not understand.

Example 3: A boy talks about the experiments with proteins. The other students make notes and ask him when they do not understand. Sometimes he cannot answer the question and then they ask the teacher. “I am not sure. We must ask the teacher to help us with” Then they have a discussion in which all in the group is involved and they open up for new questions about protein.

Class B

In many situations from the videos the boys and girls are very good at telling their classmates about the experiments they have done and their conclusions from the experiments. Sometimes the listening group make notes but often they only listen to the report. If the students have done the same experiments they compare and discuss their results. This can be illustrated by the following examples.
Example 1: A girl tells the others very good about what her group has done and about their conclusions. The others listen and nod approval when they recognize results from their own experiments. Sometimes they ask questions. The listening students do not make any notes.

Example 2: A girl reports from the experiments and sometimes she asks her group friends about something. The students in the listening group are not active and look at other things in the classroom.

They discus an unexpected result: when they put sugar in lemon juice the pH-value does not increase. In everyday language sour taste is opposite to sweet taste. They are very surprised and discus why the pH-value does not rise when the lemon juice tastes sweeter and less sour.

Example 3: One girl is responsible for the report and does it very good and gesticulates and you can see how interested she and the others in the group are. Often she discusses with one of her group friends about the experiments. The listening girls are very interested.

In summary the analysis of the videos show examples of different ways of interaction teacher-students and students-students.

<table>
<thead>
<tr>
<th>Video cut from a laboratory lesson</th>
<th>Teachers comment to the video cut.</th>
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<tbody>
<tr>
<td>Teacher: How could hydrogen be formed?</td>
<td>Teacher: Emil is very active he is sure of his theory when he talks.</td>
</tr>
<tr>
<td>Emil: It is H₂O – it is water. Then it will be – we do not remember what it is called.</td>
<td>Interviewer: Is Hanna quiet during your talk?</td>
</tr>
<tr>
<td>Hanna: Sodium</td>
<td>Teacher: No Hanna knows about the elements, sodium and chlorine. She talks about hydrogen and water. Emil wants to have his ideas confirmed. I think there was a good discussion between these two clever students. I hoped that they should pep up each other because they are very clever both of them.</td>
</tr>
<tr>
<td>Emil: Yes hydrogen will be formed. We are quite sure.</td>
<td></td>
</tr>
<tr>
<td>Teacher: Why is hydrogen formed?</td>
<td></td>
</tr>
<tr>
<td>Emil: There is hydrogen in the water.</td>
<td></td>
</tr>
<tr>
<td>Teacher: Where is the water?</td>
<td></td>
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<tr>
<td>Emil: H₂O.</td>
<td></td>
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<tr>
<td>Teacher: Yes</td>
<td></td>
</tr>
<tr>
<td>Emil: Then it will be some sodium …</td>
<td></td>
</tr>
<tr>
<td>Hanna: This is chlorine</td>
<td></td>
</tr>
<tr>
<td>Emil: Chlorine?</td>
<td></td>
</tr>
<tr>
<td>Hanna: Yes</td>
<td></td>
</tr>
<tr>
<td>Emil: Chlorine – it is also in water in pools</td>
<td></td>
</tr>
<tr>
<td>Hanna: No</td>
<td></td>
</tr>
<tr>
<td>Emil: Yes everything will be to hydrogen.</td>
<td></td>
</tr>
<tr>
<td>Teacher: When we put this ball model here will it be water then?</td>
<td></td>
</tr>
<tr>
<td>Teacher: Can you see that hydrogen is being formed?</td>
<td></td>
</tr>
<tr>
<td>Emil: There will be bubbles?</td>
<td></td>
</tr>
<tr>
<td>Teacher: Yes, that could be possible</td>
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</tbody>
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Interviews with the teachers
The teacher in class A says that the students are quite used to work and discus with each other in groups. She thinks it is interesting to study when they try it out in a laboratory
lesson where the students have to report on experiments to another group that has not
done the same experiments. The students have had a written test on foodstuff at the end
of this part of the science course and she has not found any differences for single
students in the results on the questions about fat and proteins.

One problem she has found is that some very ambitious students responsible for the
write-up use long time before they are satisfied. The others in the group become
irritated.

The teacher comments students’ work in the videos:
The students in one group call because they want to test if their thinking is correct.
The students discuss what they have done and what they shall report on.
It is important that it will be understandable for the students and that you act on the
students’ ideas.
The student is very eager to talk. He likes to talk about what he has done.
This is from the presentation and I wanted to help the two not so clever students that
had to do the presentation. (In the video the teacher listens to a presentation and asks,
“What was the task? What had you to find out?”)

In one presentation the students talk about fat molecules and one student talks about
alcohol in liquor and in fat. The teacher says that the students had attendant questions to
discuss.

The teacher is very satisfied with many presentations. She also says that looking at
and discussing the video cuts is very instructive for her.

The students are very active. This boy is not very good usually but here he is very good. It
was very pleasant! When looking at the video I see many new things. In the lessons I am so
involved and think it works very good. You don’t get any confirmation of how it is. It is very
pleasant to see these videos.

The teacher in class B emphasises how important it is for the learning environment that
the students have different roles in the groups of three during lab work. She argues that
this strategy makes the work more equal. Otherwise there is a risk that some students
dominate. The strategy has also developed the students’ ability to listen to others and to
participate in an exchange of opinions.

In a few occasions some of these 15-year-old students talk with success about science
phenomena to primary students (12-year-olds). Working with different roles has also
given the secondary students a better self-confidence and they have acquired important
knowledge to talk about. They realise how much science they have learnt.

The teacher says:

It gives them a better self confidence. They feel that they have important things to say and
that they themselves have learnt a lot. It is not many years since they were fifth-graders!

The teacher sees that the students spend more efforts to explain to students with
difficulties to understand. The teacher says:

I think they get a deeper understanding of science phenomena, when they talk to classmate
that have problems to understand. You have to think it over carefully before you say
something.

I have seen a good co-operation. They take up and change roles without complaining. They
look to change to another group with excitement.
The teacher argues that the students have developed their knowledge in chemistry because they have not been passive listeners but participated actively in the laboratory work.

In summary the analysis of the interviews with the teachers shows that looking at video cuts gives the teachers opportunity to discover unseen interactions between students and between themselves and students.

Summary
The video recordings and the interviews with students and teachers show that the interventions stimulate the students’ work. The students are more focused on understanding the science content of the experiments than in the 1st teaching unit. In most of the reporting to another group there are intense discussions often followed by discussions with the teacher. Sometimes the teacher after listening to the discussion asks a follow-up question. During a few reports there are hardly any discussions. One group read from their paper and the other writes it down.

Both the students and the teachers claim that the reporting to another group facilitates the students’ understanding. In the interviews, many of the students discuss how reporting to another group and listening to the report from another group influence on their learning and understanding. The teachers also notice new aspects in the students’ argumentation and learning processes, and how the students understand the instructions.

In the interviews the students use their science knowledge. They often can talk about what the other group has reported. When the students are asked what they have learnt from the teaching sequence 3-4 weeks earlier many of them do not spontaneously remember that in detail. But when asked questions about what they did in the laboratory lesson, many of them can give a detailed description using science knowledge. They talk about for example pH-scale, acids and bases, coagulation of protein, or dissolving of fat. Often the concepts are linked to the experiments.

The teachers focus both on the communication and on the students’ learning when commenting on the situations in the video cuts. Sometimes they notice new aspects of students’ argumentation and understanding.

Conclusion and implication
This study supports Lemke’s (1990) argument about the role of communication when students do lab work in science. The students in this study state that both the discussions in the groups and between students and teacher have a positive effect on their learning.

The ideas from Nakhleh, Polles, & Malina (2002) about distributed cognition have pointed out different types of interactions in the laboratory lessons. Students’ learning and understanding about the subject field is interpreted from their description of the experiments, as well as from their descriptions of and comments on the way of work in the laboratory lesson. The analysis of the videos focuses students’ discussions and reporting about their experiments in the lessons. The teachers who know the students very well have commented on students’ work and cooperation, and their own role in the communication with the students when looking at video cuts from the lessons.
The intervention based on ideas about reciprocal teaching introduced by Ann L. Brown (1992) stimulates the students’ interest, and their understanding of the tasks when doing lab work. When the students have to report their results to other groups of students they stimulate each other and refine their conceptions. The ‘reciprocal teaching’ design facilitates the students’ participation in the discussions about the experiments. The students seem to use more time for reflection on their different roles. The students have many different opportunities during the intervention to develop their own conceptions when discussing what happens in the experiments (Leach & Scott, 2003). The intervention also stimulates new types of interactions between teacher and students. On students’ initiative they discuss what happens in the experiments, and how to describe and explain what happens. When the students report to another group the teacher listens to the presentation. Then the teacher widens the discussion. This study shows many evidences for how communication stimulates students’ learning during lab work activities.

Many possibilities to develop Brown’s ideas can be seen in this project. The present study is a valuable contribution to the improvement of learning science by describing different ways of stimulating students’ development of their ability to meaningful communication and cooperation in science classrooms. Discussions about video cuts from lessons can also be an important tool for teachers in order to develop their teaching ability.

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