Preparation for a Laboratory Exercise
- the effects of writing a summary

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Abstract

This degree project has studied how a changed preparation affected students' outcome of a laboratory exercise. Through use of cognitive load theory and sociocultural theory a guided writing of summary was designed. Students in secondary school were let to prepare for a laboratory exercise through a traditional teacher led introduction or the guided writing of summary. Data was collected as observations, worksheets, tests and evaluations. Results suggest that the guided writing of summary facilitated a construction of cognitive schema supporting students' method. This made them follow instructions and understand purpose of the laboratory exercise before and during the exercise in a better way than students preparing through a teacher led introduction. Furthermore students' perception of aim of the exercise shifted from theoretical work afterwards to theoretical work before and practical work during the exercise. This shows an improved understanding of links between theory and practice.

Keywords: science education, pre-lab, learning outcome, secondary school.

Sammanfattning (in Swedish)

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1. Introduction

Take a look in a dictionary for the word science and you will find it means the study of structures and behaviours through observations and experiments (Crowther, J., Kavanagh, K & Ashby, M., 1995; Collins Cobuild English Dictionary, 1995). If you continue to spend some time by the bookshelf and look in a natural science book, for example in physics or biology, you will find that those experiments and observations became an integrated part of science in the seventeenth century (Hewitt P.G., 2006; Campbell N.A. & Reece J.B., 2005). Science has since then been based upon experiments and certainly is today (Hofstein & Lunetta, 2003). In education this is manifested partly in reading about science history but mainly in the laboratory exercises, or practicals. It does not matter whether it is the syllabus of biology, physics or chemistry (Biology A, 2000; Chemistry A, 2000; Physics A, 2000; South African National Curriculum Statement in Physical Sciences, 2003) the laboratory exercises will, or at least should according to these instrumental documents, be a part of the subject. A review of research about laboratory exercises was made by Hofstein & Lunetta (2003) who found that these exercises are promising a great deal of opportunities and should be a part of the modern science education but at the same time they are not always delivering as students are often having problems with this part of the curriculum. The reason for this is not fully understood but research points in the direction of the cognitive processes taking place in the working memory (Sweller, van Merrienboer & Paas, 1998; Johnstone, Sleet & Vianna, 1994; Winberg & Berg, 2007). The preparation before the laboratory exercise is seen as instrumental to the learning outcome (Chittleborough, Mocerino & Treagust, 2007) but as Limniou, Papadopoulos & Whitehead (2009) notes, the lecture which is a common preparation is not always actually preparing students for the laboratory. It seems like the laboratory exercise is a hard road to follow but still one that has to be wandered.

Adding to the problem of students not understanding the laboratory exercise is the economics. These exercises are usually quite expensive when compared to other forms of lessons as there is a need for trained staff, often specially designed class-rooms, equipment and in some cases waste management. On top of this the exercises are frequently time consuming as an effect of students sharing space and equipment and due to the element of change that is often needed to take place. In today's schools laboratory exercises are facing the grim face of a tightening budget. This problem is of course even greater in developing countries. Rollnick, Zwane, Staskun, Lotz & Green (2001) note that in South Africa an erratic earlier schooling and language issues adds to the problem.

Most of earlier research discussed above has been focusing on laboratory work at university level but this study is set in a secondary school. This has several implications. Other academic load, described by Rollnick et al. (2001) as the load of work that comes from other simultaneously studied subjects, will have a negative impact on the students' focus. As most students at a secondary school level study a larger number of separate subjects albeit at a lower level than university students this can have an effect. The laboratory exercises that have been used in earlier studies are all longer than the usual secondary school exercise and this is also reflected in the time used for preparation. Furthermore secondary school students in this study have not yet had an opportunity to choose what subjects to study whereas university students have made this choice. This can be reflected in the motivation to study. All these differences give this study further relevance as little research of this kind has been conducted at this educational level.

This study will look into whether an alternative way of making students at a South African school prepare for a laboratory exercise can help them in understanding the aim, method and theory of the exercise.
1.1 Questions and guidelines

Two questions are posed which are serving as guidelines for this study.

- How does a change in preparation before a laboratory exercise, aimed at helping students to maintain an adequate level of free working memory during the exercise, assist the learning outcomes of the laboratory exercise?
- How does a change in preparation before a laboratory exercise, aimed at students' working memory during an exercise, assist the students' understanding of connections between theory and practice?

The first question is closely linked to the Cognitive Load Theory which asserts that when the human brain experiences an overload of information the cognitive processes that are crucial to learning are impaired (Sweller et al., 1998; Bannert, M., 2002). When applied at students' struggle at understanding laboratory exercises this means that the learners are confronted with too many impressions and considerations for them to fully concentrate on learning. The aim of the study preparation is to help students to maintain an adequate level of free working memory so that they can organize their impressions and considerations and consequently focus on performance and learning (Johnstone et al., 1994).

The second question is an addition to the first in that it investigates if a higher level of free working memory during exercises will help students to construct links between theory and practice. This is a recurring problem to teachers as noted by Burrowes & Nazario (2008); students do not relate theory and practice as parts of a whole, rather they are seen as two different subjects. If working memory could process information with less of a hassle during the exercise then the conceptual understanding of the exercise would be facilitated (Sweller et al., 1998).

2. Theoretical Background

For this study literature has been studied in the areas of laboratory exercises, cognitive load theory, sociocultural theory and pre-laboratory exercises and this review is presented below.

2.1 The Laboratory Exercise

To the National Swedish Agency for Education laboratory exercises are important to students both as sources of information and as a means of learning (Biology A, 2000; Chemistry A, 2000; Physics A, 2000; Science studies, 2000). Educators in South Africa share the view of the laboratory exercises' importance (South African National Curriculum Statement in Physical Sciences, 2003) as do the educators at the Association for Science Education and University of Cambridge International Examinations (International Practical Science Guide, 2006). The reason to why the laboratory exercise is seen as so important has to do with it being an integral part of natural science both in history and today. The literature review by Hult (2000) listed seven general purposes for laboratory exercises. Laboratory exercises can [author's translation]:

- Be a complement to the theory, showing the application of the theory.
- Develop the ability to be analytical, critical and to formulate goals.
- Help students to learn in a meaningful way.
- Facilitate the understanding of scientific work.
- Give experience and practice of laboratory techniques.
- Motivate to further science studies.
- Develop the social competence and communicative abilities.
This is in close relation to the goals set up by Sjøberg (2005) who asserts that practical work can be directed towards the derivation of scientific laws, the assertion of the laws and theories, using theory, using equipment, helping students' motivation, self-confidence and routines (both working alone and in teams). Other researchers have listed arguments such as: laboratory exercises present students with opportunities to construct knowledge in a meaningful way (Chittleborough et al., 2007), doing so cooperatively with other students in a very special learning environment (Hofstein & Lunetta, 2007) while also increasing their conceptual understanding (McKee, Williamson & Ruebush, 2007).

From a more pessimistic perspective the same researchers list arguments like: laboratory exercises are too expensive and take to much time (McKee et al., 2007; Chittleborough et al., 2007), students are not prepared to perform the exercises (Rollnick et al., 2001; Limniou et al., 2009) and teachers are having problems to assess students' work in laboratory (Hofstein & Lunetta, 2007). One difficulty in connection to the last argument pointed out by Sjøberg (2005) is the use of exams that only target theoretical understanding. According to Sjøberg, the PISA and TIMSS studies show a small or zero relation between students' total score and their amount of experience of laboratory work. Many researchers and teachers have identified students' behaviour during laboratory exercises as the following of laboratory guidelines like a recipe in a cookbook. This is interpreted to show that the students have little understanding of the purpose of the exercise or too little knowledge or skill to implement their knowledge into the exercise (Hofstein & Lunetta, 2007; Limniou et al., 2009; Rollnick et al., 2001).

Laboratory exercises today then are a must in science education but they are accompanied by a number of difficult issues. In the end it all comes down to the question of whether these exercises help students form their knowledge in an efficient way. In educational systems employing an outcomes-based perspective, such as Sweden and South Africa, the teacher must measure the learning outcome of education. Both these educational systems are based on the individual learner (Lpo 94, 2006; South African National Curriculum Statement in Physical Sciences, 2003) and her or his learning outcomes. If the teacher is unsure of the goal of the laboratory exercise, the same will probably be even more true for the students. Högström (2009) has recently shown in a study of science teaching in Swedish secondary school that the perception of objectives of laboratory exercises often differ, not only between teachers and students, but also between teachers and their instructions to the exercises. As research has shown, laboratory exercises can be a hard part of the curriculum for many students but why is this? The answer may lie in the way that we use our prior knowledge to form new knowledge.

2.2 Cognitive Load Theory

The Cognitive Load Theory (CLT) is based upon the assumption that the brain has two separate kinds of memory; long-term memory and working memory. The long-term memory is where we store facts, images, sounds etc. and its capacity for storage is almost unlimited. The working memory is used to remember information during short time lapses but is also used to manipulate this information and serves as an interface between perception, responses and the long-term memory. The capacity of the working memory is contrary to the long-term memory very limited (Baddeley, A. 2003). When the working memory processes information it uses a schema, or as Donovan, Bransford & Pellegrino (1999) puts it, a conceptual framework: a plan about how to sort out the new information. Both Donovan et al. (1999) as well as Sweller et al. (1998) recognizes that a person with experience from a certain field is likely to have constructed a precise schema of how to process information from this field.

Johnstone et al. (1984; 1998) argues in line with this that the teacher has incorporated a well
functioning schema and thus has organized her/his knowledge, lowering the intrinsic load, being able to discard the extraneous load and as a result can focus attention to a laboratory exercise. The proper functional schema helps to organize the knowledge so that it can be accessed and applied with a decreased usage of working memory. Automation of schema gives the working memory an easy access to the most useful rules which allows for the information to be processed (Sweller et al., 1998).

The human brain's functions are located in a number of more or less specialized areas. When the brain is performing two activities at once chances are that the activities will need attention at least in part from the same area of the brain. This results in a competing situation where the two activities disturb each other in that they divide the attention of the brain. Studies have been made of which areas of the brain that are functioning as bottlenecks for the processing of information. In experiments testing the ability to perform simultaneous tasks the bottleneck areas coincides with the areas responsible for the working memory (Klingberg, T., 2007). It seems that the working memory sets a limit for the number of processed elements of information in the brain (Sweller et al., 1998). From the perspective of CLT this means that when the cognitive load has become too heavy, i.e. there are too many elements of information, the brain can not longer function optimally.

The cognitive load can be divided into three sources: intrinsic, extraneous and germane. Intrinsic cognitive load is emanating from the studied material. When high interactivity with the material is needed this load will be high. High intrinsic cognitive load should therefore be expected when studying a new subject or a new concept is introduced. The extraneous cognitive load comes from poor instructions or other sources of disturbances that are not contributing to learning. Consequently high extraneous cognitive load occurs for example when the language is not understood or instructions are ambiguous. The germane cognitive load is resulting from processes where the learner construct schema or learns deeper knowledge (Bannert, 2002).

Sweller et al. (1998) argue that the formation of schema is the construction of links between single elements of knowledge. When a relation between two elements is created this allows these two elements to be treated as one schema by the working memory which decreases the number of simultaneous tasks in the working memory. As further single elements of knowledge are built into the schema, this construction gains an advantage over processing single elements of knowledge. Instead of having the working memory processing multiple elements of knowledge one single schema can be processed which leaves more free working memory. Schema are formed then as the learner interacts with material in such a way so that it can be linked to previous knowledge. This is in close connection to sociocultural theory's assertion that our understanding and learning is built on our previous knowledge (Anderson, Greeno, Reder & Simon, 2000).

Johnstone et al. (1984; 1994) and Pickering (1987) argue that the student thus has to construct a schema on her/his own in order to be able to focus on the right things, that is to discard the “noise” and to receive the “signal”. If the student is not able to use a schema the extraneous cognitive load in form of noise will force the student to the “cook-book laboratory” and rote memorization. Students lacking an appropriate schema will experience high extraneous cognitive load which will use large amounts of working memory leaving less of it to understand and interact with the information (intrinsic load) and even less for the working memory to deal with the germane load. But as Sweller et al. (1998) stress, it is not only a high extraneous cognitive load that is a threat to understanding, it is also the lack of schema dealing with the intrinsic cognitive load. Construction of schema also has the ability to ease the interaction with elements of intrinsic cognitive load.

Some CLT-guided research has been carried out to study the effects of preparation for a laboratory.
Johnstone et al. (1994) let students read, plan, calculate and report in advance of the laboratory and this is argued to have been beneficial to the students as they experienced less noise. Winberg & Berg (2007) let students perform simulations, in close conceptual relation to the laboratory, arguing that this led to a decrease in students' cognitive load and a clearer view among the students of what was important in the following laboratory. Sweller et al. (1998) lists methods that endow the development of schema: goal-free problems, exploring, worked examples (solutions) and completion problems (partial solutions) all increased the construction of schema in comparison to conventional one-end problems.

### 2.3 Sociocultural Theory

According to sociocultural theory learning is participation in a social context (Dysthe, O., 2003; Anderson et al., 2000). Learning thus occurs when individuals interact with others and material, compared to cognitive approaches which are more focused on the individual's ways of structuring knowledge (Anderson et al. 2000). Dysthe (2003) reviews the sociocultural theory and asserts that communication is a central theme in sociocultural theory and through the use of "tools", intellectual and practical resources e.g. language, when communicating in a context knowledge is created. As Dysthe (2003) interprets sociocultural theory learning is: situated in a context, mainly socially, distributed among people, mediated through tools, dependent on language and participation in a community. The importance of context is emphasized which means that the individual is not only in a context (as in cognitive approaches) but is indeed a part of the context. Knowledge and understandings are distributed among people, implying that everybody does not understand everything the same way. Through social interaction with others and the resulting combination of differing perspectives knowledge and further understanding is created. For the learning environment in a laboratory exercise and the preparations to it this implies that students need to interact with other students. New knowledge is always in relation to previous understanding but is not internalised individually, rather learning is seen as a joint process with the context where communication using tools is the medium. This lends further importance to the social interaction that takes place when working and discussing with others and therefore the interactivity with others is crucial to learning according to sociocultural theory. As communication using tools is instrumental in the meeting with others, language being the foremost tool is equally vital as interactivity. To let students communicate and use their tools they should be engaged in some sort of open-ended exercise.

Another central concept in sociocultural theory is the zone of proximal development describing the potential development between what the learner can do on her/his own and what is feasible with support from somebody else who has a deeper understanding of the studied area. For the teacher this does not mean a constant watch over students, it is more about acting as a mentor. This mentorship when students are preparing for a laboratory exercise can be expressed for example through the instructions or a well planned discussion. "Scaffolding", social support e.g. the teacher's role as mentor or the discussion of viewpoints with a peer, helps the learner through two processes: construction of knowledge by problem solving, guidance and feedback but also the internalisation of knowledge. For a good sociocultural learning environment learners' high contextual interactivity with material and people is thus needed but also guidance and support from the teacher.

### 2.4 Pre-Laboratory Exercises

When students are facing a laboratory exercise the usual preparation planned by the teacher is a lecture\(^1\). What usually happens during this lecture is that important concepts are either repeated or

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1. Note that this “lecture” at level of secondary school usually is a lot shorter than a lecture, i.e. ten to fifteen minutes.
introduced, the procedures of the exercise is examined and the goal is presented. This is supported by researchers (for example Hult (2000); Limniou et al. (2009)) and has also been observed during this study. During a laboratory exercise students need a number of skills in order to deal with laboratory activities e.g.: observing, classifying, using equipment, appliance of conceptual knowledge, procedural knowledge, interpretation of data (Chittleborough et al., 2007). These varying tasks often need to be done simultaneously which is very demanding on the working memory but as Chittleborough et al. notes, a diligently prepared group of students can maximize their benefits of the laboratory exercise. Pogačnik & Cigič (2006) suggest that an increase in pre-laboratory work directed towards a better understanding can reduce the cognitive overload. Over the last decade a number of studies have tried alternatives to the lecture as means of preparation; integrating a software program in the pre-laboratory session (Winberg & Berg, 2007; Limniou et al., 2009), letting students work with an on-line exercise consisting of questions then giving feedback (Chittleborough et al., 2007), writing synopses of the coming exercise (Rollnick et al., 2001), preliminary sessions and tests (Pogačnik & Cigič, 2006). The conclusions drawn from these pre-laboratory exercises vary; students’ aim of the laboratory exercise shifted and a better schema of knowledge helped students to a more theoretical view of the exercise (Winberg & Berg, 2007), the feedback and the opportunity to learn from it was much appreciated among students (Chittleborough et al., 2007), preparation in form of obligatory writing of synopsis helped the students to focus on the important parts of laboratory (Rollnick et al., 2001), students with a relatively weak educational background were integrated in the educational process and post-laboratory work was decreased (Pogačnik & Cigič, 2006).

An important notice is that the mentioned research has been done at university level and that the preparations usually has taken place in a session separate from the laboratory exercise. The laboratory exercise at university level is also usually longer than one hour. In secondary school the usual laboratory exercise is about one hour and the preparation is usually done in the beginning of the lesson. Exercises in both Pilot and Study were 55 minutes long.

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The word lecture is used to describe the method of introducing the exercise rather than implying a concept of time.
3. Method

The study consisted of two separate parts; a pilot study and a subsequent experimental study, figure 1. The pilot study consisted of four types of preparation which were applied in one control group and three experimental groups. Observations of the pilot study were carried out during preparation and exercise and data was collected as worksheets together with evaluation forms. The findings from the pilot study were worked into the design of the study which consisted of one control and one experimental preparation. The control preparation was a teacher led introduction and experimental preparation was designed as a guided writing of a summary, for full instructions see appendix E. Both control and experimental preparations were applied in two classes each. Observation of the study was carried out during preparations and exercises and data was collected in form of a pre-test, post-test, worksheets and evaluation forms. First the pilot is presented with an analysis of it and then the study preparation is presented. Results and discussion of study is presented in the sections Results and Discussion.

According to the principles of the school where the study took place it acts as the legal guardian during the time students attend school. The school therefore is to see to the students' best in place of parents or other guardians. Because of this the ethical considerations concerning the study were discussed with local staff and necessary precautions were taken. The researcher made himself known to the students during a couple of weeks in advance. All students were informed of the study.

3.1 Pilot

The laboratory exercise chosen for the pilot study was dealing with the concepts of mass, volume and density. A worksheet was handed out to the students comprising of some theory and method, leaving room for a hypothesis, results, a discussion and conclusion. The students were handed three or four sets (depending on class size) of differently sized cubical objects, each set made of a single substance, e.g. copper or wood. Through the measurement of length, width and height volume could be calculated and this was to be compared and related to the mass of the object. Discussion about the possible relation between mass and volume followed and a conclusion summed it up. The students worked in groups of three to four students in each.

3.1.1 Sample

The study was performed at a boys only school in the province of KwaZulu-Natal, South Africa. This school is a privately funded school and so the students here are from relatively economically strong families. Many of the parents are private business owners, farmers, doctors or teachers. White students are in a majority but a growing number of students are Black, Indian or other Asian nationalities. The school uses the University of Cambridge International Examinations' curriculum. There are a number of different first languages at the school (English, Afrikaans, Zulu and Xhosa are common) but in the classroom everybody uses English. The school runs classes from grade 0 up to grade 12 but most of the students are in secondary school. This means that many students start at the school in grade 8 which is also the year when Physical Science comes into right as a subject on its own. As the students come from different schools there are sometimes quite large differences in their science knowledge (though most have had a good primary schooling) and in some cases language can be a problem. Thus whilst the school is definitely better funded than most South African schools it still experiences the same problems with second language acquisition and differing prior schooling many poorer schools do as was observed in situ and reported by Rollnick et al. (2001).

As pointed out by Rollnick et al. (2001), the best form of preparation is subjective and because of
this an approach where the pilot study tested a maximal number of different preparations were chosen. Findings from the pilot study could then be used in the design of the preparation in the study where only one type of experimental preparation was to be used. For the pilot study four parallel physical science classes taught by three teachers were chosen together with local staff. In order to get as much data as possible from the pilot study one class was designated control group (n=20) and the other three were experimental groups (n_{ex.1}=17, n_{ex.2}=21, n_{ex.3}=21). This way three different types of preparation could be tried. The teachers responsible for the physical science subject in the four classes met once a week to keep track of the course and classes but the teachers were free to individually plan their lessons. The only lesson that the study affected was the start of the laboratory exercise and the end of it when students were asked to answer the evaluation form.

![Diagram](image)

Figure 1. The general setting of the study. The control preparations were the teachers’ usual introductions to the exercises. In the pilot study experimental groups were in order 1-3; group discussions, answering questions individually and writing of summaries. In the study the experimental groups both did the same preparation, working in pairs, answering questions and writing a summary.

### 3.1.2 Preparation exercise

With the control group the teacher was instructed to do the same preparation as usually. Together with the teacher this was estimated to take roughly fifteen minutes, the other preparations were designed to take the same amount of time to complete. It was important to keep time on task equal between groups since additional time allows for additional preparation. Some extra minutes were however given to the experimental classes since the teacher had to give instructions as the methods
were new to the students. Experimental preparation groups had five minutes to read through and fill in the hypothesis and method, then ten minutes for their specific preparation.

The control preparation was held by the teacher who led a discussion concerning theory, hypothesis and methods mentioned on the worksheet with the class. During the discussion the teacher (together with answers from students) indicated what the hypothesis would be and how to fill in the blanks in the method. The teacher handed out questions in the class, and nearly everybody was at least at some stage involved with a question.

In the pilot study three types of preparations were used; group discussion, individual work and the writing of summary. All the experimental preparations included a presentation of the method and purpose of the preparation. The conclusion of Winberg & Berg (2007) that the preparation sends a signal of what is important in the exercise, was taken into account. This study has relied on both cognitive and sociocultural perspectives which has lead to three general principles of learning (Anderson et al., 2000) which have been instrumental in designing the preparations:

- the need for an active learner in the learning process,
- the impact of social elements on learning and
- the organization of earlier knowledge.

The first point was reinforced by shifting focus from the teacher as the active leader to the students. Although the teacher in the control group was discussing the exercise with the students, handing out questions even to the unwilling ones, the centre of attention was still at the teacher. The degree of participation influences the perceptions of ownership of the tasks which is reflected in the motivation to work (Stensaasen & Sletta, 2004). For the second point it was important that the students had an opportunity to act socially and in that way form and re-shape their knowledge and understanding. According to CLT the organization of earlier knowledge (i.e. schema) guides the approach and thinking and one of the purposes of the preparation was to help the students organize their knowledge so that they easily could apply that knowledge. Tasks that Sweller et al. (1998) argued to facilitate the construction of schema were open-ended, exploring, worked examples and completion examples.

All three experimental preparations began in the same way; the teacher introduced the exercise, then let the students read and answer the questions on the worksheet. The first experimental preparation was a group discussion where the groups of three to four students first were to read through the theory, aim and method on their worksheet. They were then asked to discuss a number of guiding questions but they could also discuss their own questions. The guiding questions were constructed to deal with procedures (i.e. how to measure), concepts (e.g. connections between mass and matter), and the overall method (i.e. the scientific method). To facilitate a discussion the questions drew examples with familiar objects (such as differences in mass, if any, between wood and lead). Through these measures the students were made more active and instead of just writing down answers socially refining their knowledge. The usage of familiar objects in examples were to facilitate the organization of earlier knowledge.

The second experimental preparation was similar to the first one in all but one crucial aspect; the students did their preparation individually. The questions were essentially the same though they had been rephrased to better suit individual answering instead of group discussion. Though not keeping in line with the importance of social interaction this method gave an opportunity to measure if the discussion in groups was fruitful. It also put further pressure on students to be active as the only one answering the questions were themselves. Both first and second preparation deals with open-ended
work which have the possibility to help construction of schema as suggested by Sweller et al. (1998).

For the third preparation an individual summary of the theory, aim and method was to be written by the students. Earlier studies by Rollnick et al. (2001) had concluded that the writing of summaries prompted the students to interact more intensively with their laboratory manuals. This would agree well with the first point, the active learner. This preparation can be characterized as exploring, or even as a worked example, which according to Sweller et al. (1998) eases the construction of schema.

3.1.3 Collection of data

Evaluation form
To understand how the students perceived the preparation an evaluation form was used. It was filled in either at the end of the lesson or to be handed in the following lesson (due to some classes not having time at the end of their lesson). The evaluation form was focusing on whether students thought that the preparation helped them during the laboratory exercise. For the evaluation form to be compatible with the aims of the study five questions (see appendix A) were devised focusing on proceedings, focus, interpretation, theory and aim, e.g.; "the preparation gave me an understanding of the theory in the practical". Each question was answered by marking one of four answers ranging from "not agreeing", via "agreeing to some extent" and "agreeing to a large extent", to "totally agreeing". The opportunity to express other ideas or suggestions were given at the bottom of the evaluation sheet.

Observational guidelines
It has been proposed by Johnstone (1997) that questions posed by students can reflect their cognitive focus during laboratory work and further studies made by Berg (2005) have shown this. Winberg & Berg (2007) used an categorising observational schema in order to collect data about questions and they stress the non-invasive character and therefore conclude the method to be a suitable way to study students' behaviours in a normal setting. The above studies have taken place at university level and to make it work in a secondary school setting not only questions but also other utterances by students were considered eligible. The reason for this inclusion was that after observation of laboratory exercises at the school (before the study) it was clear that students not always asked the teacher but rather were talking and discussing among themselves. Because of this including utterances was believed to yield more data. To facilitate the observations some guidelines were devised.

The observational guidelines was developed with the "on-off observation" described by Johansson & Svedner (2006) as an important source of inspiration. The on-off observation is a type of categorising observation where a number of well defined categories of behaviour are worked out in advance and after observation during a specified time lapse, the behaviours are placed into the categories. The on-off observation prescribes that students are observed, one at a time after a list, and that behaviours are categorised as either on (the expected behaviour) or off (other behaviour). The advantages to this method are simplicity as it is usually no difficulty at determining whether a behaviour is on or off, the time lapse which makes time for observation equal and the observational order. Time lapse and observational order make it easier for the observer to avoid bias and choosing which behaviours to observe. The main disadvantage to categorising observations is that the previously made categories are hard to apply in a holistic way and as a consequence do not capture the importance of things in a classroom. Since the aim of the observation was not to capture what happens as a whole but rather individual or group behaviour (in forms of speech) the disadvantage was not considered severe to the study.
The observational schema, table 1, was constructed with on-off categorisation with expected behaviour as showing understanding and other behaviour as showing little understanding in four areas; apparatus, calculations, theory and aim. The first category was chosen as a way of recording students' behaviours when understanding of the concept was shown (for calculations e.g. "multiply three sides of a cube in cm gives volume in cm$^3$") and the second category was chosen to record behaviours when students showed that they did not understand the concept or understood it only partly (e.g. "Should I multiply or add? Which unit should I use?"). This approach meant a deviation from the on-off observation as a lack of observed on-behaviour did not necessarily mean a presence of off-behaviour. The classes were divided into groups which were working alongside the walls of the classroom and the observer spent one to two minutes at each group before moving forward. Each group was thus observed during several stages of the exercise.

During the preparation in experimental group two observation was carried out to see how the students worked as groups. This observation did not have the same planned observational guidelines, instead it focused on participation of the members of the groups and how discussions went. The control group was also closely monitored during the preparation as this was important for the comparison between control and experimental preparation. This observation was of descriptive character.

Table 1.
The observational schema used in pilot.

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Calculations</th>
<th>Theory</th>
<th>Aim</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students talk about apparatus showing understanding</td>
<td>Students talk about calculations showing understanding</td>
<td>Students talk about theory showing understanding</td>
<td>Students talk about aim showing understanding</td>
</tr>
<tr>
<td>Students talk about apparatus showing little understanding</td>
<td>Students talk about calculations showing little understanding</td>
<td>Students talk about theory showing little understanding</td>
<td>Students talk about aim showing little understanding</td>
</tr>
</tbody>
</table>

3.1.4 Results of pilot

Worksheet
All the groups used the same laboratory worksheet which allowed a comparison. The aim with the analysis was to compare the worksheets qualitatively.

- In the control group, more than 25% of the students did not make a hypothesis. Over 90% of the students in the group filled in the blanks in the method part correctly. More than 30% of the students had problems with the calculations.
- In experimental group one, where students were answering questions individually, there were more students struggling with the hypothesis than in the control group. The method was about as correctly filled in as in the control group, a few more students had some problems, but the calculations were a problem to a larger number of students in this group than in the control group.
• In the second experimental group, doing group discussions, fewer worksheets than in the control group were lacking hypothesis. There were more cases of inconsistencies between suggested methods in the method part and realized method (i.e. suggesting to use millimetres but using centimetres) and some had the wrong answers (i.e. using a scale to measure length). There were about as many problems with the calculations as in the first experimental group.

• The third experimental group, writing summaries, had a larger number of hypotheses than the control group and the method part was a little bit poorer. Even though a larger number of worksheets than in the control group was missing calculations, this was the group with the largest number of conclusions in the worksheets. All of the conclusions were not correct.

Observations
The observations resulted in a total of 24, 21, 29 and 15 (control, experimental one, two and three) numbers of recorded behaviour. There were too few observations of behaviour to draw any conclusions about differences in on-off behaviour between the groups in all four areas (apparatus, calculations, theory, aim). Relatively few observations of talk about the aim were recorded.

It was noted that many students acted in ways that showed both understanding and little understanding in various areas.

Evaluation form
Agreeing with the assertion meant being positive to the preparation. Answering as not agreeing at all was considered a level one answer, agreeing to some extent was a level two answer, agreeing to a large extent was a level three answer and totally agreeing was a level four answer. The only answers from a group that were much different from the other groups were concerning theory where a larger number of students from the control group considered that the preparation gave them a good understanding of theory.

Usage of the possibility to comment was not evenly spread as experimental group three gave 12 individual comments, more than the other groups combined (11). The comments were usually positive, some gave suggestions (e.g. "working in teams of two", "we should draw a diagram") and a few wanted clearer instructions. Through a symptomatic interpretation (Kvale, 1997) the reason for the majority of positive answers was analysed as a result of expectation bias, what the students considered as good answers. This is described by Ejlertsson & Axelsson (2005) as socially desirable answers which essentially means the same thing but focuses more on the social situation.

Analysis of pilot
In the control group the teacher during the preparation practically gave (though asking students for suggestions) all answers needed for hypothesis and method. This is related to the kind of one-end questions (since one type of answer is chosen as correct) that Sweller et al. (1998) argues as not facilitating the construction of schema. In the first experimental group (individual work) most of the students worked in silence and answered all the questions. Many of the students did not give correct answers to conceptual questions (i.e. "do blocks of lead and wood of the same size have the same mass? - Motivate") but there were also students who made correct statements here while in the worksheet (filled in minutes earlier) failed to make a hypothesis. In the second experimental group (group discussions) the hypothesis and method parts of the worksheet were filled in during group discussions. This was manifested in groups of three to four students having the exact same answer. Most of the groups showed one or two students taking a leading role while one or two students just sat and listened. It was also noted that some of the ideas brought forward were reinforced as the students discussed it. Most groups only discussed the questions handed out to them and not their
own questions. Some students in experimental group three (the writing of summaries) found the instructions hard to understand and were having questions about what they were supposed to do. Most of the summaries were concentrating on describing the procedure but a large number did also have a hypothesis included in the summary.

There was no evidence that any group could handle the cognitive load in a better way than the other groups since observation according to the pre-made guidelines did not yield significant results. However, it was noted that although the control group did the teacher led introduction where hypothesis and method was correctly filled out, the control group did not achieve much better results than other groups. The large number of conclusions in experimental group three could be argued to signal a better connection between the practice in the exercise and the theory. It did not matter that some conclusions were wrong since all conclusions show an interaction with the material and the theoretical knowledge that goes to it.

### 3.2 Study

For the study, biology in grade nine was chosen in the same school as pilot. The laboratory exercise took place over two lessons, a pre-test was used and one control preparation and one experimental preparation, observation was carried out during preparation and practical work and post-data was collected as a laboratory worksheet, an evaluation form and a post-test, figure 2.

The laboratory exercise was consisting of two separate exercises, see appendix C and D for full instructions, both were about transpiration in plants demonstrating that plants lose water through their leaves. In the first exercise two similar sets of water filled beakers were used. In one beaker a leafy shoot is placed, then oil is poured on the surface. In the other beaker a leafless shoot is used instead. Beside the beaker an indicator of water vapour is placed (cobalt chloride paper or anhydrous copper sulphate). A bell jar is then placed over beaker and indicator and plasticine is used to seal the experiment. After a couple of days the bell jars are examined to see if the indicator shows presence of water vapour or if there even are water droplets on the inside. The expected result is that the indicator has changed colour only in the bell jar with the plant and perhaps even a presence of water droplets on the inside of the jar. For the second exercise two plant species and two measuring cylinders are used. The plants are placed in the beakers, a measurement of water level is made, then oil is poured on surface. After a couple of days the water levels are measured again to see if there are any differences in transpiration. The expected result is that the water levels have dropped differently for the two species. Each class was divided in two halves each doing one
of the exercises and each half was divided into groups of three to four. As the second exercise had a short set-up time, groups doing that exercise were also given a third exercise with focus on xylem vessels. This exercise was not done by all groups and so it was not part of the study. Due to transpiration taking some time, the exercises were taking place during two lessons, the first for the set-up and the second for recording of data and analysis. The worksheet to both experiments consisted of aim, apparatus, method, results and questions to be answered after the experiment. Note that instead of vaseline as mentioned in the laboratory manual plasticine was used.

3.2.1 Sample

The classes were in grade nine and two teachers had two classes each in biology. These classes had been formed after results in exams, i.e. academic achievement, and thus two classes showed high academic achievements and two classes showed lower academic achievements. This was examined through study of three earlier exam results in biology. The school uses a grading system where the individual score is set in proportion to the total score. Level seven indicates 80 % - 100 % of the total score and level one indicates 0 % - 29 % of the total score. In between these extremes are levels two up to six all with a range of ten percent each. When all three exam results were taken together a picture was revealed of the classes' exam results, figure 3. Each teacher had one strong and one weak class each so the results could not be due to differences between the teachers. The classes were labelled control 1 (n=25), control 2 (n=24), experimental 1 (n=24) and experimental 2 (n=25). In cooperation with the teachers a time plan was worked out so that each class would have had the same amount of "theoretical" lessons before the laboratory exercise. One of the teacher was to do the control preparation for both control classes while the other teacher were to do the experimental preparation for both experimental classes.

Since the two classes were two almost identical sets of one high achieving and one low achieving class each, see figure 3, the experimental set of classes was considered to be a representative sample of the entire population and only the pre-tests from this set was collected. The students in the two control classes did the pre-test too but not before they had started with the laboratory exercise.

![Figure 3. Aggregate results from three previous exams in biology for the four classes in the study. The level is related in percentages to the score on the exams where seven is the highest score.](image-url)
3.2.2 Preparation exercise

The control groups' preparation was the teacher's usual introduction. It was discussed beforehand and a time frame of 15 minutes was agreed which then was worked into the experimental preparation. In the control groups the teacher discussed the exercise with the students in the order of the instructions but also seemed to have the questions on the worksheet in mind. The function of the oil, plasticine and indicator was discussed. The teacher explained a few practical details (e.g. measuring water level at meniscus) and talked about the concept of transpiration. The low academic achieving class got some additional help compared to the other class. From discussion with the two teachers involved in the study the designed experimental preparation was a new method to the students, thus a few more minutes were given them so the teacher could explain it.

The experimental preparation was designed with the following findings from the pilot study in mind:

- As some students in experimental group 1 showed ability to express the relation needed for hypothesis through a question but not without it, it was considered vital to help students to make a hypothesis by providing guiding questions or considerations.
- Experimental group two showed how a discussion can have the effect of making answers homogeneous and reinforced (the effect of polarization; Stensaasen & Sletta (2004)), and at the same time students with good understanding helped the ones not understanding. Because of this some kind of group discussion in smaller groups was considered. This approach also gives way to the social interaction which is crucial in sociocultural theory.
- Summaries from experimental group three showed a focus on explaining procedural issues (and that this group had a quite good methodology). This was also discovered by Rollnick et al. (2001) who in later stages of their research included more guidance in how to write a summary in order to shift students’ focus. As this approach showed at least partial gains it was considered for the study preparation.
- Experimental group three showed a larger number of conclusions than the other groups. This shows theoretical connections to the laboratory exercise.

As the findings suggested a clear and somewhat more extensive guiding it was seen as important to keep the instructions in a straight progression. To make the preparation work it was also crucial that the instructions were easy to understand and the number of students at the school having other first languages than English gave further relevance. This need was met by introducing the preparation to students from one grade below who were not participating in the study, letting them give feedback on the preparation. In order to help formation of schema the preparation should also be formed as open-ended, exploring, worked and completion examples (Sweller et al. 1998). For an appropriate preparation it was vital to understand which parts of the laboratory exercise that could present difficulties and which parts were crucial to the outcome of the exercise. This matter was investigated with an experienced teacher at the school. Three parts were identified: "oil on surface of water level", "bell jar dry" and "copper sulphate". The reason why these parts were so instrumental to the outcome of the exercise were identified. If the shoot is pushed through a layer of oil the shoot can be covered in oil making water inaccessible to the roots thereby preventing transpiration. If the bell jar is not dry then there may be water left on the inside which will make the indicator (copper sulphate or cobalt chloride paper) show the same result under both bell jars. If the copper sulphate (or cobalt chloride paper) is not heated and dried it can not indicate a change from dry to humid. These critical parts were also considered difficult for the students and possible sources of both intrinsic cognitive load (as one correct interaction was requested) and extraneous cognitive load (as the students needed to identify these instructions as very important thus there is a need to identify noise and signal). Practical details restricting the design were the time frame, the number and seating of students and material needed for the preparation. One last point to stress was
also the need for the students to read the instructions. The considerations for the elements of the worksheet are listed in table 3. For the resulting preparatory exercise, guided writing of summary, see appendix E.

Table 3.
The considerations for elements of the worksheet.

<table>
<thead>
<tr>
<th>Part of preparation</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>Working in pairs</td>
<td>Findings in pilot study. To allow for a social interaction and to minimise the risk of low achieving students not preparing in any way. The groups could have been bigger for the social interaction but on the other hand this would have made the writing part more difficult.</td>
</tr>
<tr>
<td>Reading instructions</td>
<td>The importance of a thorough reading of instructions could not be underestimated, thus this was reflected in the preparation. In connection to this it was also mentioned which part of the instructions that should be read.</td>
</tr>
<tr>
<td>Question about the scientific method</td>
<td>Findings from pilot study. As the scientific method was an integral part of the laboratory's setting, this was included in order to focus attention to this concept.</td>
</tr>
<tr>
<td>Answer to question</td>
<td>To avoid students having totally incorrect conceptions of the method an answer was provided.</td>
</tr>
<tr>
<td>Writing a summary</td>
<td>Findings in the pilot study and earlier research. This method forces an interaction with the material in an exploratory way.</td>
</tr>
<tr>
<td>Guiding to summary</td>
<td>Findings in the pilot study and as earlier research by Rollnick et al. (2001) pointed out that students were helped through instructions. The guiding would help to steer clear of a total domination of method in the summary but also as the guided areas were considered difficult and crucial.</td>
</tr>
</tbody>
</table>

3.2.3 Collection of data

Observational schema
The failure to collect enough data in the pilot study meant that the observational schema had to be revised. Instead of using a categorising schema the method of observing critical incidents (Johansson & Svedner, 2006) was chosen. For this method incidents that are critical to the study are defined and when such an incident occurs this is observed and recorded as it happens. The advantage of this method is that it is easy to use when the object of the observation occurs several times but in short time lapses and is easy to define. The major disadvantage for this study was that the observation was running a risk of being centred around one or a few active groups.

Incidents considered as critical were students asking questions to the teacher (which was used by Winberg & Berg (2007)) and behaviour that concerned theory or procedures. Critical procedures was further defined as "oil on surface of water level", "bell jar dry" and "copper sulphate". These were areas that a discussion with an experienced teacher revealed as potentially difficult but also crucial to the outcome of the exercise. Instead of the passive observer suggested by Johansson & Svedner (2006) the observer was recognized as having to venture out into the classroom to be able
to identify the critical incidents. To alleviate the observer's task the operating groups were considered as the units of observation (not for individual students asking questions). The control groups were observed in order to describe the teacher's introduction and the students' response.

Worksheet
All worksheets from the laboratory exercise were collected, for the full instructions on worksheet, see appendix C and D.

Summary
The summaries from experimental groups one and two were collected.

Pre-test
The pre-test was a part of the course, a homework sheet with "check your progress"-questions to complete before entering the laboratory. One of the questions had a similar setting\(^2\) as both the laboratory exercise and the post-test and the answers were therefore examined closely and labelled A-D. A-level answers showed a total understanding, B showed a partial understanding, C showed little or no understanding and D indicated that no answer had been given. For the rest of the pre-test worksheet the students' understanding of transpiration was studied.

Post-test
The post-test was a homework sheet that summarised the section "transportation in plants" that the classes had been through. This test was similar to the pre-test. Two questions\(^3\) in the post-test were analysed with the same method as described in the pre-test. All the classes were to hand in their post-tests.

Evaluation form
The same evaluation form was used as during the pilot study, see appendix A.

\(^2\) Two similar tubes were filled with the same amount of water, in tube A a freshly cut leafy shoot was placed and held in a position with a piece of cotton wool. A similar piece of cotton wool was put into tube B but without the plant. Measures of mass in tube A were taken every ten minutes and for tube B after one hundred minutes. When the results were compared the mass of tube B exceeded that of tube A. What was the purpose of tube B?

\(^3\) The first task showed the same experimental setting as the pre-test question, but the time frame was twenty four hours, and the question was "why did the students need to set up flask B?". The second question was "what is the purpose of having a control?".
4. Results

Results from observations, worksheets, summaries, pre-test and post-test are presented in this section.

4.1 Observation

Observation of the control groups' preparation showed that the teacher first let the students read through instructions and then discussed the exercise as mentioned in 3.2.2 Preparatory Exercises. Some of the students were very active and some were less active. Control group one participated in greater numbers than control group two.

Observations yielded information about procedural critical incidents showing differences between control and experimental groups. All groups in control group one and two put the shoots in the water after oil was poured on the surface, and no group wiped the bell jar dry. Many groups in control group two did measure accurately and all the groups sealed the bell jar with plasticine. Most of the groups in both control groups did not follow the order of the instructions. In experimental group one every group put the shoot in the water before the oil was poured on the surface and all wiped their bell jars. The dehydration of the copper sulphate was carried out by the teacher (with some help from students) and for experimental group one this process took a long time. This resulted in some of the groups not having time to completely seal the bell jars. In experimental group two almost all the groups put the shoot into the water before the oil and almost all groups wiped the bell jars. In both experimental groups all the groups followed the order of the instructions except for the groups that did not have time to finish. The observation of questions to the teacher did not show any significant differences between neither the control and experimental groups nor the stronger and weaker groups. The control groups did their exercise in a higher tempo than the experimental groups.

When examining the bell jars it was clear that the copper sulphate or cobalt chloride paper had turned blue under every bell jar in every group, there was in some of the experimental groups' control bell jars left a colour nuance of pink.

4.2 Worksheet and summary

In control group one, the indicator's change in colour in the control bell jar was by many students attributed to bad weather, e.g. "water vapour is trapped in bell jar when we began due to the weather conditions". All of the students noted that the change of colour in the experimental bell jar was due to water vapour in the bell jar and most of them added that this was caused by transpiration. In the experimental bell jar there were in some cases water droplets on the inside of the jar. All of the students showed through their answers that they understood the purpose of the oil layer, the copper sulphate and the plasticine (vaseline). As precautions the students in total gave five different answers; do not break the bell jar, get a healthy plant, do not break the stem, do not push the roots through the oil and the need for a large root system. There were some students making the wrong conclusions about rate of transpiration and how suitable a plant would be in a dry environment but most students answered correctly. All students answered that transpiration occurs through the leaves and some mentioned stomata.

Control group two's students saw the colour change in the experimental bell jar as an evidence for transpiration and in the control bell jar as a sign for water vapour in the air. In some of the experimental bell jars water droplets could be seen on the inside of the jar. The purpose of the
cobalt chloride paper is clear to all students and almost everybody has understood the purpose of the oil layer. About half of this group saw the sealing of the bell jars as blocking water from the outside to get in, the other half saw it as blocking water from getting out. Precautions stated by this group are; see that the plants are alive, that the stem is not broken, that the bell jars are dry, that the water levels are equal, be careful with the bell jars. Water loss is explained to occur in stomata, root hair cell, leaf and xylem vessels.

For experimental group one there were some droplets on the inside of the experimental jars. The colour change in both bell jars were noted by most students to be a result of water vapour but some did not report anything in the "control bell jar field". The purpose of the oil layer is understood as is the purpose of sealing the bell jars. Almost all of the students have understood the purpose of the cobalt chloride paper and copper sulphate. Some of the students doing exercise three had not filled in the worksheet, but among those having filled it in the answers were generally correct. Precautions are stated as; not to break the shoots, sealing the bell jars properly, healthy shoots, same amount of water. Most of the students showed an understanding of transpiration and that water loss occurs through leaves and stoma.

In experimental group two the colour change was noted to take place in both bell jars. Some students mentioned transpiration as a source of water droplets on the inside of the bell jars. The purpose of the oil layer was clear as was the reason for the cobalt chloride paper. The answers to why plasticine was used were all dealing with the sealing of the bell jars but a small number of students were mentioning CO$_2$ and O$_2$. Precautions stated are: shoots must be healthy, not getting the shoot wet when preparing it, the bell jars must be dry, making sure oil covers the surface, accurate measurements. All students showed an understanding of transpiration and that leaves and stoma are responsible for the loss of water.

The summaries from experimental group one and two were collected. In experimental group one most of the groups had written aim and method more or less as in the instructions. Not all the groups had answered the questions but some had integrated the questions into their method and some other groups had answered them separately. Some of the groups had written a hypothesis. One group had made a summary more or less answering what the purposes are of aim, method and hypothesis. In experimental group two most of the groups had written an aim, some method and a hypothesis. Most summaries answered the guiding questions as ordinary questions (i.e. not integrating these answers with the method). One group had only written down the aim.

### 4.3 Pre-test and post-test

Pre-test answers were labelled A-D according to the shown level of understanding where A indicated a full understanding (e.g. "to have an experiment to compare A with"), B a partial understanding (e.g. "to see how much water evaporated [sic]") C a minor understanding (e.g. "to see what absorbs water quicker") and D no answer at all. From experimental group one 18 worksheets were collected and from experimental group two 18 worksheets were collected, table 4. Answers from the rest of the worksheet showed that experimental group two had a good understanding of transpiration. In experimental group one many of the students did not understand the concept of transpiration.

For the post-test answers from control group two have not been sent to me. Therefore this column is left blank until I receive this data. The answers were labelled using the same system as with the pre-test, table 4.
Table 4.
The results from pre-test and post-test of students understanding of the transpiration in plants. A-level answers indicated a full understanding, B a partial understanding, C a minor or no understanding at all and D no answer at all.

<table>
<thead>
<tr>
<th>Level of answer</th>
<th>Experimental group 1 (n=18)</th>
<th>Experimental group 2 (n=18)</th>
<th>Experimental group 1 (n=26)</th>
<th>Experimental group 2 (n=15)</th>
<th>Control group 1 (n=36)</th>
<th>Control Group 2 (n=)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>9</td>
<td>8</td>
<td>12</td>
<td>22</td>
<td>no</td>
</tr>
<tr>
<td>B</td>
<td>5</td>
<td>5</td>
<td>6</td>
<td>1</td>
<td>4</td>
<td>data</td>
</tr>
<tr>
<td>C</td>
<td>6</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
<td>data</td>
</tr>
<tr>
<td>D</td>
<td>2</td>
<td>2</td>
<td>7</td>
<td>0</td>
<td>5</td>
<td>data</td>
</tr>
</tbody>
</table>

4.4 Students' evaluation

The evaluation sheet was analysed the same way as the pilot evaluation. Agreeing with the assertion meant being positive to the preparation. Alternatives ranged from "I do not agree" via "I agree to some extent" and "I agree to a large extent" to "I totally agree" and answers were labelled in that order as level one to four. Control group two had one non-response to the question about theory. Results for questions concerning proceedings during exercise and the help to focus during the exercise are shown in figure 4, and together with all evaluation results in appendix F.

![Figure 4. a) The number of answers to evaluation assertion that preparation did help the proceedings during exercise. b) The number of answers to evaluation assertion that preparation did help the focus during the exercise. 1 represents not agreeing at all, 2 agreeing to some extent, 3 agreeing to a large extent, 4 totally agreeing.](image-url)
5. Discussion

First the formation of schema and the perceived aims of the exercise is discussed. Then follows a discussion about the post-testing and students' evaluations, continuing with implications for teaching and finally a word on further research.

5.1 Formation of schema and aim of the exercise

The observation of the critical incidents "oil on surface of water level" and "bell jar dry" showed that experimental groups and control groups differed in behaviour. Every group in both control groups put their shoot in after the oil had been applied whereas almost every group in both experimental groups put the shoot in before the oil had been applied. The same behavioural patterns emerged when analysing the drying of the bell jars; neither group in the control group did this but almost every single group in the experimental groups did. These patterns of behaviour could be argued to be caused by influence of other groups; as one group started to wipe the bell jar dry other groups realised this and followed en suite. This however contradicts the finding that only almost all groups in the experimental groups wiped the bell jar. If group influence is argued to be instrumental then a larger number of groups should have had a more profound influence and all groups should have manifested the same behaviour. It can also be asserted that the experimental groups did not understand why they had to do these things and just followed the instructions in order to get through, i.e. a cookbook laboratory. This would be revealed through an analysis of the summaries and the worksheets since students who had to resort to a cookbook laboratory were not expected to perform well on these tasks. An examination of the summaries showed that some of them were not well written but most of them were at least adequate and quite many had answered the guiding questions in some way. The laboratory worksheets showed no significant difference between the control groups and the experimental groups but most worksheets demonstrated an understanding of the concepts. These findings refute the argument that the experimental group displayed a cookbook laboratory.

In order to complete the worksheet some work had to be done by the students, theoretical considerations and practical work, and this workload can not have been distributed similarly between the groups. This conclusion is derived from the observation of experimental groups having performed method and considerations they described in their worksheets. Control groups had a discrepancy between their performed method and considerations and the ones they reported in the worksheet which means that the control groups must have made the reported considerations after the practical part of the laboratory. The experimental group on the other hand probably made their considerations during or even before the exercise as their observed considerations and methods were the same as they reported in their worksheets. When examining the summaries this proposal was supported by the students' handling of the guiding questions (which focused on the same parts of the exercise that were observed as critical incidents). Thus the experimental group did some theoretical work at the preparation stage that the control group did only after the exercise.

According to studies of CLT and instructional design by Sweller et al. (1998) the formation of schema is facilitated by exploring, open-ended and completion exercises and will reduce intrinsic and extraneous cognitive load. Johnstone et al. (1994) argues that the implementation of schema show itself as students making the right considerations and being able to focus on the signal. Based upon these theoretical claims and observations of the exercise I argue that formation of schema was facilitated by the guided writing of summary. Further, the observation of experimental students considering methods and then demonstrating the right method during the exercise show the existence and implementation of this schema. As students in the control groups did not display this
behaviour I conclude that the formation and implementation of the schema was due to the guided writing of a summary.

Pogačnik & Cigić (2006) points out that a major part of students' time during a laboratory exercise is usually devoted to post-laboratory work. This is supported by the control groups' focus on post-laboratory work. As observed they focused on getting through the practical part quickly and then move on to theoretical work on the worksheet, which is where they made up for mistakes in the method. As Winberg & Berg (2007) points out, the preparation sends a signal of aim and of what is important during the exercise. In accordance with this I argue that students in the control groups had a perception of the aim being oriented towards theoretical treating of the practical work. The experimental group displayed more focus on the practical part through their handling of the critical incidents. I therefore conclude that the guided writing of a summary made the students change their focus from theoretical work afterwards in favour of theoretical work before and practical work during the exercise. This marks a shift in students' view of theory and practice. Students in control groups displayed a view of practice as extra-curricular theory, being less important than the theoretical work. Students in experimental groups did focus on both theory and practice, though separately, showing that they came closer to an understanding of connections between the two.

5.2 Post-testing and the students' evaluations

When comparing pre-test and post-test some positive change in understanding was noted. Results from the pre-test showed that experimental group one was consisting of students with lower academic achievements than experimental group two. This is supported by data from previous exams. There are no significant differences between control and experimental groups when examining the results of the pre-test and post-test. This can be argued to show that the control and experimental groups were displaying the same knowledge and that the preparations thus did not differ in their effect on the learning outcome of the laboratory exercise. This is not consistent however with the analysis if observations and worksheets. The outcome may be the same but there may be several ways to get there. It can thus be argued that the knowledge being tested was not exclusively a part of the laboratory exercise but was as much a part of the theoretical framework being studied during lessons. That would mean that students could have understood the concept during ordinary lessons or laboratory lesson implying that the pre-test and post-test were not adequately designed. This reasoning is close to the weak relation argued by Sjøberg (2005) between the laboratory work and exam results where post-testing or exams are not targeting knowledge or understanding derived exclusively from the laboratory. Högström (2009) argues that even though the teacher may have assigned objectives to a laboratory exercise, these objectives are not always evident in instructions and students may have perceived other agendas. If exams are not targeting laboratory knowledge and the objectives of a laboratory exercise are hard to discern students are indeed placed in a difficult situation. For a more revealing and rewarding post-test the unique learning outcomes of the laboratory exercise must be identified and implemented.

When examining the evaluation sheets it is interesting to note that the two control groups were more positive than the two experimental groups to the assertions that their preparation facilitated their proceedings and helped their focus during the exercise. The reason to why this is interesting is that, as was argued, it was the guided writing of a summary that facilitated students' proceedings and helped the focus during the exercise more than the control preparation. I argue that students' opinions here are a result of two factors; a case of expectation bias from the control groups expressing a praise to their teacher, and the experimental groups feeling of uncertainty when exposed to a new form of preparation. Socially desirable answers and expectation bias has a greater effect on control students' answers than the experimental students' ones. The control students' answers are affected by their relation to the teacher whereas the experimental students did not have
the same relation to the researcher. As the guided writing of summary was a new method to the students, which was confirmed by the teachers, some uncertainty could be expected and that uncertainty had a negative effect on students' appreciation of the preparation.

5.3 Implications for teaching

Sociocultural theory claims that processes of learning take place through systems of social interaction between individuals while according to cognitive theory these processes are individual constructions (Anderson et al., 2000). Since this study has relied on both sociocultural and cognitive approaches to learning it is important to evaluate the study using both views. Sociocultural theorists would argue that the learning process which the experimental group experienced during their preparation is due to the social interaction between the two students in each pair who were able to define and refine their knowledge through the meeting with the other. Spokesmen for the cognitive approach would rather say that the learning process is due to the individual internal construction taking place when the individuals interact with the material. If comparing experimental preparations in pilot and study according to the two approaches there would be two differing conclusions. But as Anderson et al. (2000) argues it is more fruitful to recognize both theories as important rather than strongly advocating one in favour of the other.

From this less dogmatic perspective the students did learn both from their interaction with the other students but also from the interaction with the material. In meeting the other, students were placed in a situation where they could talk about their perception of the phenomena but also listen. Through this meeting of minds and perceptions the students could define, not only for the other but also for the self, how the perception and knowledge looked like. This allowed for a greater understanding of the phenomena. At the same time the students were interacting with the material in such a way that links could be constructed internally between single elements of knowledge. The construction of links transformed the earlier knowledge, which was fragmented, into a unified schema. As the working memory could process the schema instead of the single elements, a better and more refined understanding was achieved. Just as Anderson et al. (2000), I suggest both perspectives should be employed in order to create educational lessons. Both perspectives have been put to use in this study and through this helped to design it.

Both Sweden and South Africa have outcomes-based educational systems focusing on the individual learner's outcomes of education. This lends further relevance to teachers' evaluation of the outcomes of laboratory exercises. Högström's study (2009) shows that students and teachers in many cases do not have the same view of objectives of the laboratory exercise which will make the outcome of these exercises uncertain. Winberg & Berg (2007) argued that the preparation sends a signal of these objectives. The individual learning outcome can never be entirely predicted but objectives show students what is important and what they should focus on. This study shows that the preparation does play an instrumental part in students perception of laboratory exercise objectives and advocates an examination of preparations in order for them to be used efficiently.

Learning outcomes according to the post-test were the same for all groups but as been argued schema had been constructed by the experimental groups. This schema alleviated the processing of intrinsic and extraneous cognitive load and led to a better methodology. The guided writing of summary also made the students focus more on the practical parts of the exercise instead of the theoretical work afterwards. This shift is argued to show that students connected theory and practice but treated them separately. In conclusion, preparatory exercises that emphasizes learner activity, social interaction and organization of earlier knowledge may improve students performance on following laboratory exercises.
For teachers with an interest in preparation exercises for laboratory exercises it is important to keep in mind that students need to be active and engage themselves with the studied material but also that the social interaction is vital in defining and refining the previous knowledge. It is also important for teachers to examine the aims of the exercises and think about how students perceive these aims.

5.4 Further research

The guided writing of summary was a new method to the students in this study. For further investigations it would be interesting with closer studies of the method in a larger time scale where students use the method for a number of exercises. As students are getting used to the method, there may be additional insights compared to the results in this study.

It could also be rewarding to examine the intrinsic cognitive load to a planned laboratory exercise as described by Sweller et al. (1998). For an analysis of element interactivity to be useful a thorough study of students who are to do the exercise must be carried out since it is their knowledge and schema that will determine how high the intrinsic load will be. After analysing laboratory exercises and students knowledge and schema a comparison between students' outcomes of exercises of differing intrinsic load could be done.
6. References


Appendix A

Evaluation form questions

1. The preparation gave me an understanding of how to proceed during the practical.
   I do not agree       I agree to some extent       I agree to a large extent       I totally agree

2. The preparation helped me focus on the right things during the practical.
   I do not agree       I agree to some extent       I agree to a large extent       I totally agree

3. The preparation made the interpretation of the results easier.
   I do not agree       I agree to some extent       I agree to a large extent       I totally agree

4. The preparation gave me an understanding of the theory in the practical.
   I do not agree       I agree to some extent       I agree to a large extent       I totally agree

5. The preparation made it is easier to understand why we do the practical.
   I do not agree       I agree to some extent       I agree to a large extent       I totally agree
The number of answers in students’ evaluation of pilot preparation. a)-e) represent answers to assertions about proceedings, focus, interpretation, theory and purpose (for full questions see appendix A). 1 represents not agreeing at all, 2 agreeing to some extent, 3 agreeing to a large extent, 4 totally agreeing. Exp. gr. 1 had one non-completion answer in b), c) and e), and exp. gr. 2 had one non-completion answer in a).
Appendix C

Laboratory Exercise 1

Grade 9

Transport in Plants

March 2009

Name: ____________________________________________________________

Class: __________________

AIM: To demonstrate that plants transpire mainly through the leaves

APPARATUS/CHEMICALS
1. Two of each of the following: bell jars, glass slabs, beakers
2. Small quantity of oil
3. Vaseline
4. 1 leafy twig, 1 leafless twig
5. Blue cobalt chloride paper or anhydrous copper sulphate

METHOD
1. Place a leafy twig in a beaker of water.
2. Pour some oil on the surface of the water.
3. Place the beaker on a glass slab.
4. Wrap the inside of a bell jar to ensure that it is dry. Affix a strip of blue cobalt chloride paper to the upper inside surface.
5. Line the rim of the bell jar with vaseline; then place the bell jar over the beaker.
6. Repeat the above steps, but this time use a leafless twig. Smear vaseline over those sections of the twig from which the leaves have been removed.

Leave both sets of apparatus in the sunlight for about an hour.

RESULTS
In both the Experiment and Control, describe what appears on the inner surface of the bell jar and the colour change, if any, that each piece of blue cobalt chloride paper undergoes.

EXPERIMENT

CONTROL

CONCLUSION
Name the parts of a plant mainly responsible for the loss of water (Full sentence)

________________________________________________________________________

QUESTIONS
1. Why was it important to ensure that the bell jars are dry on the inside?

________________________________________________________________________

2. Why was oil poured on the surface of the water?

________________________________________________________________________

3. Why was vaseline used on a) the rim of the bell jar and b) the leafless twig?

________________________________________________________________________

4. Explain the purpose of cobalt chloride paper?

________________________________________________________________________

5. Account for the presence, if any, of droplets on the inner surface of the bell jar of the CONTROL.

________________________________________________________________________

________________________________________________________________________

6. State two precautions that must be observed in preparing twigs in this investigation. Give reasons for observing these precautions.

________________________________________________________________________

________________________________________________________________________
Appendix D

Laboratory Exercise 2

Grade 9

Transport in Plants

Name:.................................................................

Aim: To demonstrate that different plants transpire different quantities of water.

Apparatus:
1. Measuring cylinder
2. Living shoots

Method:
1. Measure 100 cm³ of water into each measuring cylinder.
2. Place leafy twig into each cylinder, re-measure the water level.
3. Pour a layer of oil over surface
4. Place experiment on a sunny window sill.
5. Leave apparatus for a couple of days then measure water levels.

Results:

<table>
<thead>
<tr>
<th>Type of plant</th>
<th>Amount of water loss (cm³)</th>
<th>Total amount of water loss (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Day 1 Day 2 Day 3</td>
<td></td>
</tr>
</tbody>
</table>

Conclusion:

The .................................. leafy shoot lost (................. cm³) of water and plant B lost (................. cm³) of water. Hence plant ........... lost more water through transpiration than plant .......... .

Questions:

1. Name the part of the plant responsible for the loss of water: ...........................................
2. Why was oil poured on the surface of the water? ..............................................................
3. Which plant lost the most water? .........................................................................................
4. Which plant would it be best to plant in a dry area? ...........................................................
5. State two precautions that must be observed in preparing shoots in this investigation. Give reasons for observing these precautions.

..................................................................................................................................................
Appendix E

The designed Study preparation

Your task is to prepare yourself for the practical by following the instructions below.

1. Take your time to carefully read the instructions (AIM, APPARATUS and METHOD) to practical 1 and 3.

2. Together with your class mate next to you discuss the question below.

   In science there are usually a number of factors (variables) contributing to a final result.

   How can we investigate the contribution of a single factor to the final result?

   Write a short answer here:

   If you set up two identical experiments and change only one thing between them you can see the contribution of one single factor

3. Continue to work with your partner. Together you will write a brief SUMMARY of the practical including AIM, METHOD and a HYPOTHESIS.

   It will help you a lot if you study the instructions very carefully (you can return to them any time during the preparation). Follow the instructions down below. Use any free sheet of paper.

   a) your AIM: What are we trying to show with this practical? (Consider the fact that we do this practical during the section "Transportation in plants").

   b) your METHOD: Write a short summary of the method and include explanations to the following:

<table>
<thead>
<tr>
<th>Practical 1</th>
<th>Practical 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Why do we pour oil on top of the water?</td>
<td>Why are we measuring the water level?</td>
</tr>
<tr>
<td>Why must the bell jar be dry and then sealed air tight?</td>
<td>Why do we pour oil on top of the water?</td>
</tr>
<tr>
<td>Why are we using anhydrous (dry) copper sulphate?</td>
<td>Why do we wait for a couple of days?</td>
</tr>
</tbody>
</table>

   c) your HYPOTHESIS: Describe what will happen in your experiment. Remember that the section that we are working on right now is "Transportation in plants".
Appendix F

*Students' evaluation of Study preparation*

The number of answers in students evaluation of study preparation. a)-e) represent answers to assertions about proceedings, focus, interpretation, theory and purpose (for full questions see appendix A). 1 represents not agreeing at all, 2 agreeing to some extent, 3 agreeing to a large extent, 4 totally agreeing. Ctrl. gr. 2 had one non-completion answer to d).
Acknowledgements

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