The Nature of Teacher Discourse during Practical Work in Lower Secondary Physics Education

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Master's Thesis

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Abstract

This work is a study on teacher's discourse during practical work in lower secondary schools in Finland. The point and goal of this study is to illustrate the situation as it is in the classrooms and, hopefully, to inspire teachers to observe, contemplate and modify their discourse during practical work.

A qualitative content analysis was done on eight videotaped physics lessons on the topics of electrical power, energy and the cost of electricity. The content of teacher discourse was studied in the framework of, on the one hand, the tangible objects and observations and on the other hand the abstract theories and models of physics. Particular attention was paid to link-making between these two domains in the teacher's discourse. The teacher discourse was categorised as either belonging to the domain of ideas I, the domain of objects and observables O or making links between these two domains I/O. Also an analysis of the nature of classroom interaction was included to provide the background for the teacher discourse: this covers both the phase of the practical activity and the form of classroom interaction.

The key findings were that a gross majority of teacher discourse during practical work was in the domain of objects and observables O. Discourse purely in the domain of ideas was practically non-existent during practical work, but there are some links being made between the domains I and O (i.e. discourse in the domain I/O). However, the amounts of these are not impressive across the board. Furthermore, these links are made almost exclusively during teacher-centered instruction, so there would be great potential to increase their number during the actual experimental work (which in this study meant student work in most cases). The results of this study imply that teachers should pay more attention to their discourse during practical work and more actively make links to the theoretical knowledge behind the phenomena.

Tiivistelmä

Tämä Pro Gradu-tutkielma käsittelee opettajan puhetta kokeellisen työskentelyn aikana suomalaisissa yläkouluissa. Työn tavoite on esitellä tilanne kouluissa sellaisena kuin sen on nyt ja siten toivottavasti innostaa opettajia tarkkailemaan, pohtimaan ja muuntelemaan omaa puhettaan kokeellisia töitä ohjatessa.

Työn analyysiosuudessa tehtiin kvalitatiivinen sisällönanalyysi kahdeksalle videoidulle oppitunnille. Tuntien aiheita olivat sähköteho, sähköenergia ja sähkön hinta. Opettajan puheen sisältöä tutkittiin yhtäältä havaintojen ja käsinkosketeltavien asioiden ja toisaalta fysiikan abstraktien teorioiden ja mallien kannalta. Opettaja puhe luokiteltiin kuuluvaksi joko ideoiden piiriin *I*, esineiden ja havaintojen piiriin *O* tai sellaiseksi, että se luo yhteyksiä näiden kahden piirin välille *I/O*. Tämän lisäksi aineistosta analysoitiin luokkahuoneessa tapahtuvan toiminnan laatua, jotta opettajan puhetta voitaisiin tarkastella sen viitekehyksessä. Tätä analysoitiin kahdessa ulottuvuudessa: kokeellisen toiminnan vaiheen ja luokkahuoneessa tapahtuvan vuorovaikutuksen kannalta.

Tutkimuksen keskeisinä tuloksina saatiin, että suurin osa opettajan puheesta kokeellisen työskentelyn aikana kuuluu esineiden ja havaintojen piiriin *O*. Sellaista puhetta, joka olisi puhtaasti ideioiden piirissä, ei esiintynyt juuri laisinkaan. Sen sijaan *I/O*-tyypin puhetta esiintyi jonkin verran, mutta valitettavasti sen määrä vaihteli voimakkaasti eri opettajien välillä. Lisäksi havaittiin, että tällaista puhetta esiintyi lähes yksinomaan opettajakeskeisen opetuksen aikana, jolloin opettaja luennoi ja kyseli kysymyksiä, ja oppilaiden rooli oli lähinnä passiivinen. Mahdollisuuksia tuoda *I/O*-tyypin puhetta myös kokeellisen työskeltelyn käytännön osuudelle (joka tässä tutkimuksessa tarkoitti oppilastyötä useimmissa tapauksissa) havaittiin. Tämän tutkimuksen johtopäätös on, että opettajien tulisi kiinnittää enemmän huomiota puheeseensa kokeellisen työskentelyn aikana ja erityisesti vetää enemmän yhteyksiä kokeellisten havaintojen ja fysiikan konseptien, mallien ja teorioiden välille.

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Contents

1 Introduction

This work is a study of teacher discourse during practical work in lower secondary schools in Finland. The underline motivation for the study is the author's interest in the educational value of practical work, specifically in its effectiveness and potential in developing students' cognitive skills and understanding of theoretical knowledge in physics. Whilst looking into this subject the author came across a study suggesting that even though teachers expect students to learn cognitive skills and theoretical knowledge through practical work they do not explicitly communicate these things to the students: they expect the knowledge to arise tacitly from the practical activities [Abrahams and Millar, 2008]. Thus it seemed apt to begin looking into the effectiveness of practical work by studying teacher discourse in order to find out if teachers indeed do not bring up the theoretical knowledge during the activity.

The study by Abrahams and Millar was conducted in England, where it has been found by several researchers that although teachers expect students to learn cognitive skills and theoretical knowledge through practical work, this generally does not happen [Abrahams, 2011; Hodson, 1990; Millar et al., 1999; Wellington, 1998]. However, this subject is yet to be thoroughly studied in Finnish schools. As the Finnish educational system is considered one of the best in the world it seemed relevant to prompt the question whether we have the same problems or if something is done differently to gain better results.

In this study I aim to find answers or explanations to the questions brought up by the aforementioned studies. In chapter 2 I will go deeper into background, motivation and theoretical framework of this study, after which, in chapter 3, I will explicitly present the research questions inspired by the presented literature. In chapter 4 I will present the methodology of the study including the accumulation of data and methods of analysis. The results of the data analysis are presented in chapter 5 and discussed with respect to previous studies and the validity of the study in chapter 6. Also possible improvements to the methodology and topics for future studies are suggested in chapter 6.3.

Throughout this thesis I shall aspire to keep the discussion closely related to school life and classrooms. The goal of this work is to provide useful information for teachers, myself included, on the importance and potential of observing, contemplating and modifying one's discourse while instructing students on practical work.

2 Literature Review

In this section I will present some previous studies connected to this work. They outline both the background to and the framework of the study.

2.1 Background and Motivation

In the study mentioned in chapter 1 by Abrahams and Millar it was found that a gross majority of classroom time and discourse during practical work was used to "successfully 'producing the phenomenon"' and enabling the students to "make the intended observations" [Millar and Abrahams, 2009:59,62]. Apart from one exception all teachers used only a few minutes, if any, out of a 50-minute lesson to discuss the ideas, theories or models behind the practical activity. Furthermore, in the same study it was found that the teachers expected the students to learn the theoretical knowledge through the work but yet did not plan or implement any sort of actual effort to bring this about. In a similar manner Ntombela states in an article on practical work in South African schools that amongst teachers and teacher-students "there is a strong belief that by following steps given in the worksheets pupils can 'discover' the theory for themselves" [1999:124].

The applicability of these sorts of discovery-based or inductive views of learning in science teaching have long been challenged [Driver, 1983]. Driver et al.

point out that the theories and models of science are constructs build by people through trial, error and significant intellectual struggles, so it would be naive to assume that the students would be able to absorb the scientific knowledge by simply "'reading the book of nature"' [1994:6] and deducing the theory from their observations. Similarly Hodson argues that teachers' views on discovery learning are distorted by some faulty assumptions about the importance and potential of observations, for instance that "Explanations of these [gained] trends and generalizations, in the form of principles, laws and theories, can be extracted from these data" [1990:37]. Indeed, it was found in an extensive study by Tiberghien that "activities of handling and measurement, which are common to most labwork activities, do not seem to lead students to establish relations between the objects and events, measurements and physics concepts" [1999:188]. It is important for teachers to be aware that although axiomatically these activities are needed in order to do practical work, independently they do not lead to learning.

Another perspective on the importance of teacher discourse can be derived from the definition of effectiveness of practical work suggested by Millar et al. [1999]. It defines effectiveness on two levels as illustrated in figure 1. Box A represents the intended learning outcomes i.e. what the teacher intends the students to learn from the practical activity. This aim might be related to learning practical skills, theoretical knowledge or aspects of the scientific enquiry process and the nature of science. Box B represents the implementation of the practical task, that is how it is designed, how the students are instructed to complete the task and what sort of knowledge and equipment they have available to them. Boxes C and D represent the things that the students actually end up doing and learning. Both of these might differ from the contents of boxes A and B to a greater or lesser extent, for instance the students may operate the equipment correctly, but may not involve the sort of thinking that the teacher intended them, which leads to superficial and/or erroneous learning.

Effectiveness on level 1 clearly has to do only with the tangible aspects of the

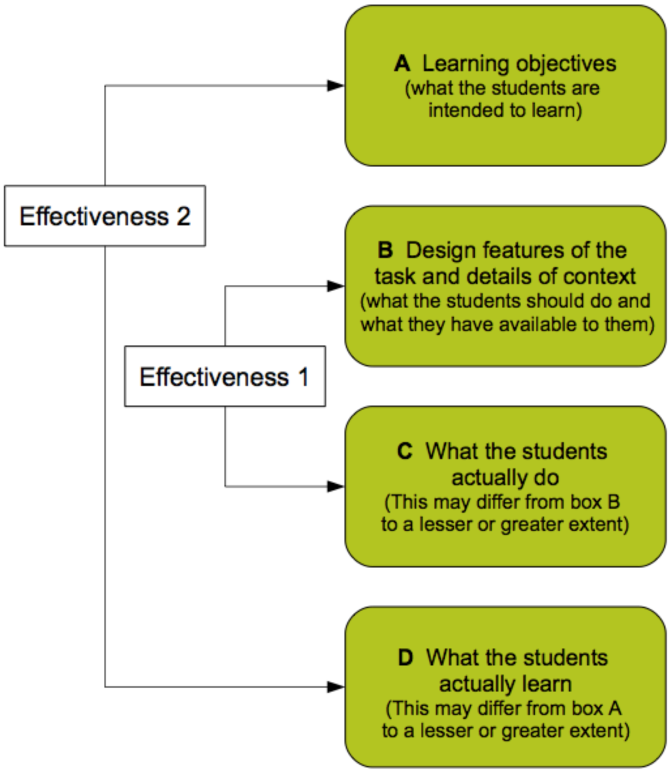


Figure 1: **A definition of the effectiveness of a practical activity on two levels (modified from Millar et al., 1999:37).**

task: what is intended to be done and what actually is done are both hands-on features of an activity. However, effectiveness on level 2 can relate to either the practical side of the task, the ideas behind the task or even both. Which one it is is defined by the learning objective of the task (box A), but regardless of the objective it can surely be stated that level 2 effectiveness is the one educators are interested in. However, it has to be recognised that level 1 effectiveness is a necessary, although not adequate condition for effectiveness on level 2.

The point of this all with respect to teacher discourse is that in order to achieve effectiveness on level 2 the students should be told the ideas they are intended to learn. In the light of the research presented in the second paragraph of this chapter by Driver et al., Hodson and Tiberghien, teachers should communicate the theoretical content of a task so that the students would be able to learn and differentiate the important aspects of it. Thus one can claim that in order to successfully instruct practical work teachers must explicitly state the ideas, theories or models behind the phenomena, or else effectiveness on level 2 is impossible.

2.2 Framework

I will begin to outline the framework of this study by defining what I mean by 'practical work'. A suitable definition is given by Millar et al. [1999:36]:

> all those kinds of learning activities in science which involve students at some point in handling or observing real objects or materials (or direct representations of these, in a simulation or video-recording).

Obviously student work is included in the definition, as well as teacher demonstrations. It should be noted that the surroundings of the activity are not outlined, so practical work is not restricted to laboratories. Simulations and video-recordings are included, rightly so due to the increasing amount of and potential in interactive means of learning. Since the writing of the above definition, also computer, tablet and smart phone applications have become common, but they will be included in 'simulations'.

Also, in the framework of this thesis I will include the discussion phase of an experimental activity as a part of practical work. According to the current views, science learning is a combination of socio-constructivist and constructivist actions [Driver et al., 1994]. The stimulation and guidance to learn new concepts comes from the classroom's social plane in the form of ideas, giving ingredients for the students to construct their own knowledge. On the social plane understanding is aspired through individuals engaging in discourse about the issues before them, so essentially learning is viewed as a dialogic process [Driver et al., 1994; Scott et al., 2011].

Another important definition is that of 'teacher discourse'. In this work teacher discourse stands for all the things the teacher says, should they be during monologue, dialogue or any other sort of communication. The content or form of the conversation does not affect whether it is discourse or not as long as the teacher is some part of it; these aspects will be categorised in the analysis.

Millar et al. state, and one can easily agree, that "the core purpose of practical activity in science teaching is to help the student make links between the domain of objects and observable things, and the domain of ideas" [1999:35]. This categorization of discourse and knowledge, shown in figure 2, illustrates the interplay between the observations of the tangible world and the abstract ideas and principles of physics. The domain of objects and observables comprises of "objects and properties that can all be directly measured or observed", whereas the domain of ideas consists of "ideas, none of which can be directly observed or measured" [Abrahams, 2011:77].

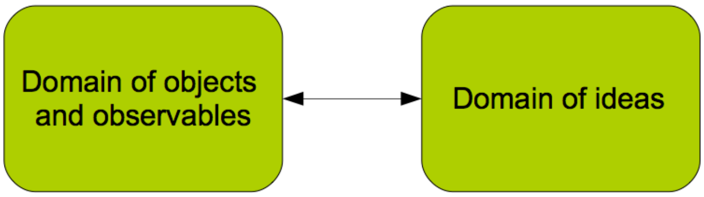


Figure 2: **The most important role of practical work is to make links between the domain of objects and observables, that is the things of the tangible world, and the domain of ideas, which comprises theories, models and concepts of physics (adapted from Millar et al. 1999:40).**

Abrahams and Millar [2008] suggest that the outcomes of practical work could be significantly improved should teachers and the authors of teaching materials recognise the importance of discussion between the domain of objects and observables and the domain of ideas: the students ought to be committed to the activities with their minds as well as their hands. Surely it can be stated that scientific phenomena are such of nature that they cannot be fully understood by neither practice nor theory: the empirical and the theoretical are intertwined and cannot be separated. Solomon uses an example of a medical student who, when seeing his very first X-ray in a lecture could not first make sense of either the picture or the lecturer's words but when comprehension came both the picture and the theory made sense simultaneously. Her point to make is that "neither the one nor the other is the primary [representation], and that neither of them alone corresponds to the full internal image" [1999:66].

In the light of the previous chapter and the socio-constructivist view of learning described earlier, classroom discussion plays a vital role in instructing and learning from practical work. An interesting study on the subject by Tiberghien [1999] found that in practical work during the experimental phase of the activity student discussion was almost completely related to the practical side of the measurements and objects and events, whereas in the data processing phase the emphasis was on the theoretical and numerical models used in the activity. However, after the practical tasks there were activities for the students to return to the experimental set up, connect a calculated quantity to some part of it and reflect how the set up could be used to modify the value of this quantity. During these latter stages the student discourse was focused on making links between the theoretical models and the tangible objects and events.

In a recent study by Scott et al. the concept of pedagogical link-making was thoroughly discussed in the context of teaching and learning science. The authors define pedagogical link-making to be "concerned with the ways in which teachers and students make connections between ideas in the ongoing meaning-making interactions of classroom teaching and learning" [2011:3]. In the light of the constructivist views of learning link-making in science, as well as all other disciplines, is vital as learning is based on links being made between existing and new ideas. Referring to the discussion above on the socio-constructivist views of learning, as new ideas are presented on the social plane the learner absorbs them through a process of internalisation, during which the learner reconstructs the information and links it with preexisting knowledge. Scott et al. argue that the role of the teacher in this process is to "address link-making on the social plane of the classroom in order to support students in constructing similar links for themselves on the personal plane" [2011:5]. In the framework of this thesis this means that the teacher uses discourse to point out links between the domains of objects and observables and the domain of ideas (see figure 2).

3 Research Questions

Here I will briefly and explicitly present the research questions of this study as inspired by the literature presented in chapter 2.

1. Do teachers in the examined classrooms use discourse purely in the domain of ideas I during practical work?
2. Do teachers in the examined classrooms make links between the practical activity and the concepts, theories and models of physics during practical work i.e. use discourse in the domain I/O?
3. During practical work, how much do teachers use discourse purely in the domain of objects and observables (O)?
4. During practical work, what kind of activities promote discourse in the domain of ideas I or link-making between the domain of objects and observables and the domain of ideas i.e. use discourse in the domain I/O?

4 Methodology

In this chapter I will present the accumulation process of the data (chapter 4.1) and the method of analysis used in this work. The method of analysis includes descriptions on the conceptual level (chapter 4.2) and the practical approach used chapter 4.3. I will also explicitly present how the answer to each research question was gained from the coded data (see table 1). Finally I will present the method of examining the reliability of the content analysis in chapter 4.4.

4.1 Collecting Data

The data collection was done by persons other than the author as a part of the international research project Quality of Instruction in Physics (see for instance Helaakoski and Viiri 2014). The accumulation process was done identically on each occasion to ensure coherent data. Eight lessons in four lower secondary schools in Central Finland were videotaped during the years 2008 and 2009: two subsequent physics lessons of about 45 minutes were recorded in each school. In each school the teacher and the class were the same in both lessons, so four teachers and four classes were observed. In two of the cases the lessons were double lessons and in the other two they were separated by a day or so.

The topics of the lessons were electrical power, energy and the cost of electricity. These topics are usually taught in the ninth grade, which in Finland is the last year of lower secondary school; this was the case in the recorded lessons as well. The pupils were approximately fifteen years of age and had studied physics for about four years (since fifth grade). The concepts of power and energy had come up earlier in other contexts such as mechanics and heat so the students should have been familiar with them, but ninth grade is the first time when electricity is studied explicitly.

Six of the eight lessons involved experimental activities; five included student work and one a teacher demonstration. The activities were quite similar, but never the same with two different groups. In addition to these one lesson involved discussion about an activity done on the previous lesson, so all in all only one of the eight lessons involved no activities related to practical work. The time spent on the practical activities varied strongly between the lessons. This is quite typical in Finnish schools: instead of whole lessons of experimental work practical tasks are used as a fluent part of any lesson [Börlin and Labudde, 2014]. The usual methods of instruction in addition to practical work are class discussion, making notes and doing calculations.

The lessons were videotaped with two cameras, one giving a general view of the classroom and the other following the teacher. The latter one of these was used for the analysis. Six microphones were used to record the lessons: one on each camera, one on the teacher and three amongst the students. As a part of the data analysis the videos were edited in a way that both the audiotapes from the camera and the teacher's microphone could be heard simultaneously. The teacher's microphone was put in as a dominant soundtrack, so it can be heard well in spite of any commotion or noise in the class. However, one can also hear the students' discourse during dialogue with the teacher from the video camera's soundtrack in the background.

4.2 Method of Analysis

The analysis was done by means of a qualitative content analysis. In this thesis content analysis is understood as "a loose theoretical framework of analysing written, heard or seen contents" (translated from Tuomi and Sarajärvi 2009:91). The actual analysis followed a typical path for content analysis [Tuomi and Sarajärvi, 2009]: the data was coded into numbers according to their qualities. These codings, or categorisations, were determined by (based on) the research questions and the literature connected to this work. Representations (graphs and tables) of the interesting qualities were produced using the coded data which will be presented in chapter 5 and reflected on in chapter 6.

The analysis is based on the interpretation of the data by the author. According to Tuomi and Sarajärvi [2009], in the post-modern view of science there are typically no means of explaining any aspects of social sciences in a purely objective manner. They further remark that all knowledge is thus more or less bound to the aspects of the research, such as the significance of the study with respect to the field of the discipline or the method of analysis. This view is rather radical, but it shall be applied in this work in order to maintain a critical perspective towards the gained results.

As suggested by Tuomi and Sarajärvi, the upside of their view is that research methods and ideas can be developed endlessly and combined from different resources. The downside, on the other hand, is that since all observations are based on "interpretations and fragmented views of knowledge", the reliability of statements and arguments has to be continuously evaluated and rigorously tested [Tuomi and Sarajärvi, 2009:55]. The former point is illustrated in this work by combining different categorisations from relevant resources into a method of analysis. The latter is taken into account by using two independent coders to test the reliability of the analysis and by critically evaluating the validity of the results with respect to other research in the field. The reliability, validity and quality of this work in general are discussed further in chapter 6.1.

Each of the videotaped lessons were analysed in two dimensions: the domain of the teachers' discourse and the nature of the activity in class. The nature of the activity was analysed because it is relevant with respect to the teacher discourse analysis: in the framework of this thesis it is quite important to know whether the activity is related to practical work when drawing conclusions on the domains of discourse. Also the form of interaction is determined to see if certain types of interactions are connected to certain types of discourse.

Obviously, the goal of the analysis was to find answers to the research questions. How this was done is presented explicitly in table 1, after which the applied analyses and how they were carried out are presented in detail in the following chapters.

Table 1: **The method of examining each research question from the coded data**

Research question	Method of examining
1	The amount of discourse in the domain I during practical work is extracted from the data.
2	The amount of discourse making links between the domain I/O during practical work is extracted from the data.
3	The amount of discourse purely in the domain O during practical work is extracted from the data and compared to the amounts of discourse in domains I and I/O.
4	Teacher discourse in domains I and I/O is evaluated in the framework of the phases of the experimental work and the activities in class.

4.2.1 Teacher Discourse Content Analysis

The teachers' discourse was categorised in three domains: discourse in the domain of objects and observables (denoted by *O*), discourse on the domain of ideas (denoted by *I*) and discourse that makes links between the domain of objects and observables and the domain of ideas (denoted by *I/O*). The categorization of teacher discourse into these three domains is based on Millar et al. [1999:41], who in fact use the same categorisation for defining a practical task's learning objective. However, one felt that it could also be used for categorising teacher discourse. The similarity might not be apparent, but surely it can be argued that the learning objectives of a task guide the teacher discourse, so the same motivation should be recognisable in both. In addition to the categorization by Millar et al. a fourth category, involving the periods when the teacher was silent or spoke about things unrelated to the physics teaching, was added to avoid distortion in the results. This shall be denoted by *S* for silence.

How different types of discourse were categorized is shown in table 2. Some

Table 2: **The categorization of the teacher's discourse and the domains to which they relate. Entry '*I* or *O*' denotes that the discourse can relate either to ideas or observables. Although the categorizations are done in singular form (e.g. a phenomenon, a fact), they also apply for the plurals (e.g. phenomena, facts).**

The contents of the discourse	Domain
Introduce a phenomenon, an object or an observable	*O*
Present a fact	*O*
Introduce a piece of equipment and/or how to use it	*O*
Present how to carry out a standard procedure	*O*
Present how to process measured data	*O*
Present how to use data to support a conclusion	*I* or *O*
Present a relationship	*I* or *O*
Present a concept	*I*
Present a theory or a model	*I*

entries in table 2 might need further clarification. 'A fact' is a factual statement, one that can be readily agreed, such as 'a light bulb will light up if placed in a closed circuit' or 'too high a current will blow the fuse in an electrical component'. A standard procedure is something that all scientists or science students carry out in the same way, such as 'if voltage and current are known, resistance can be calculated as their product' or 'an ammeter should be connected in series and a voltmeter in parallel to the examined circuit'. Practical examples on the categorizations are shown in table 9 (Appendix A). These are extracted from the data.

It should be noted that it is quite a different matter to categorise discourse as belonging to any domain in and out of context. For instance a teacher may point out a relationship between two variables, let's say electrical power and current, to show how to carry out a calculation (i.e. standard procedure, relating to the domain of observables *O*) or to present a theory (relating to the domain of ideas *I*) or to point out similarities between experimentally gained results and theoretical knowledge (making links between the two domains i.e. *I/O*). That is why it is very important to evaluate the teacher's discourse as a part of the lesson, not as an independent variable.

The discourse was analysed in intervals of thirty seconds. This means that a period of thirty seconds always gets the same categorization depending on which of the three types of discourse dominates during that period. However, there is one exception: the label *S* for silence or things unrelated to the physics teaching will only be given if the entire period of thirty seconds is of this type. If there is any subject-related discourse during the period the categorisation will be based on its content, not on the silence or the non-related discourse. This modification of analysis was necessary because this study is not concerned with discourse-silence ratios or the amount of unrelated discourse during a lesson: one is only interested in the domain of the discourse relating to the physics teaching.

The length of the thirty-second interval was chosen because it is long enough for a person to make a valid, well-justified argument, question or such, but it is short enough not to involve several of them. By dividing the analysis into these bits one is trying to get as clear a picture of the discourse as possible without going into too much detail and still being able to categorize the discourse conceptually as opposed to word by word.

4.2.2 The Nature of Activity in Class

The activities in class were analysed in intervals of thirty seconds to match the teacher discourse analysis. The analysis was done on a general level, so for the most part more than one consecutive thirty second periods received the same label. As a result one could synchronize the analysis of the teachers' discourse with the activity in class. Thus one has information on what sort of language the teachers uses in certain types of situations, specifically during practical work.

The activities in class were analysed in two dimensions: the forms of classroom interaction and the phases of experimental activities. The method was applied from a series of categorisations developed by Seidel [2005] and Teach [2005], respectively, as a part of a video study on physics instruction. Classroom interactions are coded as shown in table 3 and the phases of experimental activities as in table 4.

Table 3: **The category system for forms of classroom interaction (summarized from Seidel [2005:82-85])**

Label	Form of Interaction	Description
0	None	No interaction in the class
1	Lecture by the teacher	The teachers stands in front of the class and speaks uninterrupted
2	Dictation	The teachers dictates and students take notes
3	Class discussion/ class work	The teacher works with the whole class in class discussion
4	Silent/Individual work	Students work on individual tasks
5	Working with a partner	Students work in pairs
6	Group work	Students work in groups of three or more
7	Several kinds of interaction at the same time	Classroom interaction is a combination of 0-6
8	Transition	A change is being made between categories 0-7
9	Other	Classroom interaction cannot be described by categories 0 through 8

4.3 Analysis in Practice and Coder Consistency

The coding of data was done by the author in two parts: first the emphasis was on the teacher discourse and later on the nature of activity in class. Two computers were used simultaneously: one for watching the videos and another for coding the discourse and the situation. The program used for the coding was Microsoft Office Excel. Each thirty second period was labelled with a number between 0-3 for the discourse $S = 0$, $O = 1$, $I/O = 2$ and $I = 3$. The coding was done mostly so that the video of the lesson was playing on one

Table 4: **The category system for phases of practical activities (summarized from Teach [2005:94-96])**

Label	Phase	Description
E0	None	No connection to practical work
E1	Introduction	The goal, set-up, execution and instructions of the practical activity are presented
E2	Activity	The practical activity is set up and conducted, observation and measurements take place
E3	Discussion	The practical work is discussed, reported or analysed

of the screens and the coder typed a label on another screen every thirty seconds without stopping the video. However, every time the author felt that it was not immediately clear which label to give to an episode, the episode was rewound and watched again enough times to make a well-justified decision. Most times this included also transcribing the discourse so it could be studied carefully without haste.

The coding of teacher discourse was done twice. During the first round the author felt that her views on how some situations should be coded changed during the process, so a second round of coding was necessary. When doing the second, and actual, round of coding the author had a good and coherent image on how to code the data, and felt no need to do a third round of coding. The data coded on the second round was used for the final analysis, but out of interest the first and second round were compared: the discrepancies between the two rounds are shown in percentages in table 5. The differences vary a lot between the different lessons, which could indicate the need for yet another round of coding. However, this was not done due to the fact that the differences can be explained by the author's inexperience in the method and process of coding: the first round was essentially for practice. However, the reliability of the coding was checked by having a part of the data coded by second coder. This process and the results are described and presented in chapter 4.4.

Table 5: **The discrepancies between first and second round coding done by the author**

Teacher's number & lesson	The difference in coding between the first and second round [%]
Teacher 10, lessons 1 & 2	10,0
Teacher 12, lesson 1	16,8
Teacher 12, lesson 2	12,3
Teacher 20, lesson 1	17,6
Teacher 20, lesson 2	20,2
Teacher 24, lesson 1	12,4
Teacher 24, lesson 2	3,4

While coding the teacher discourse, the type of classroom activity was described by writing a short description of the type of activity (for instance 'model calculations' or 'measurements') in the same Excel spreadsheet to prepare for the coding on the nature of activities in class. The actual coding was done similarly to that of the teacher discourse, but only focusing on the activity in class. Both dimensions (the phase of the practical activity and the classroom interaction) were coded simultaneously.

Graphs were drawn from the coded data using Microsoft Office Excel (see Appendices B and C). It should be noted that even though both analyses presented in chapters 4.2.1 and 4.2.2 were done for all data, in the case of the nature of activity in class only the parts of lessons containing practical work are shown in the graphs in Appendix C and discussed in chapters 5 and 6. This has been done for the sake of clarity because in the framework of this thesis the nature of activity in class is only interesting during practical work. However, the results of the teacher discourse content analysis are presented in the graphs and discussed in full. Also, the amounts of discourse in domains I and I/O during practical work are tabulated and presented in chapter 5.

4.4 Comparative Coding

Approximately twenty percent of the data was coded by a second coder. This was done to examine the reliability of the coding and thus that of the results. The parts of data to be coded were selected by the author. This was simply because the author wished to ensure that the coded bits would include all sorts of classroom activities which might not have been the case should they have been picked randomly by the second coder.

The second coder is a newly-graduated Doctor of Philosophy, and one of the researchers to collect the original data. He was already familiar with the aspects of qualitative content analysis and the practice of coding video data into numbers, so he was instructed for the coding simply by giving him the preliminary version of this thesis including essential parts of chapters 2 and 4.2.1 and Appendix A. During the process of coding both the author and the second coder presented comments and questions which helped to focus the method more firmly. However, care was taken by the author not to reveal any details of the way she had coded the data to ensure that the second coder would not be influenced by her comments, so for instance the exemplary bits of coding presented in Appendix A were selected outside the parts of data that the second coder was to analyse.

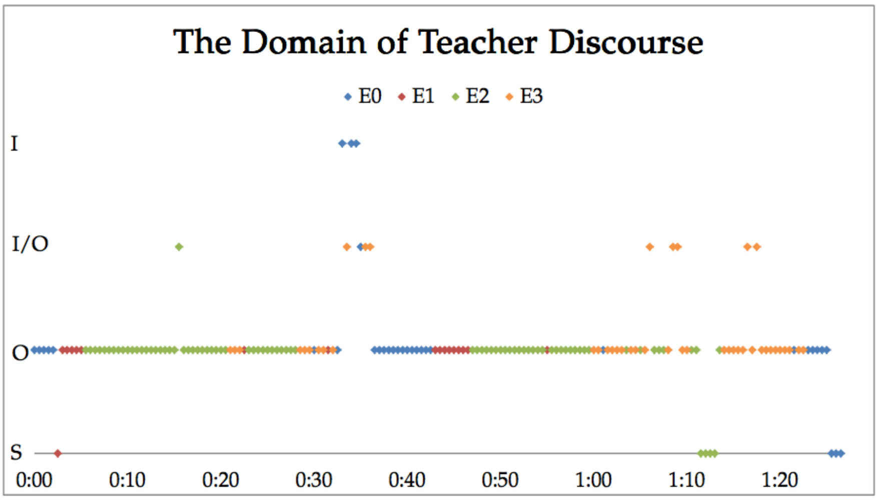
The data coded by the second coder was compared to that coded by the author. After the second coder had done the coding and sent the results for comparison, the author noted a seemingly substantial amount of differences between the codings. However, when Cohen's kappa was calculated using the statistical program SPSS to evaluate how similar the two sets of coding were the result was 0.621 which indicates a 'substantial agreement' between the two coders [Viera and Garrett, 2005]. The author had wished to gain a value of 0.7 or higher, so she and the second coder agreed that the second coder would try and code a part of the data again. This decision was made because the second coder felt that his coding in the beginning had not been entirely reliable. However, this second round of coding produced results almost identical to the first round. Furthermore, as the method of analysis was still in its infancy, the author and the second coder agreed that a substantial agreement would be sufficient at this point and if the method will be developed further in the future, they shall aim towards the highest level of agreement ('almost perfect agreement' corresponding to the kappa value of 0.81 and higher Viera and Garrett [2005]). After some reflection also the author feels content with the gained kappa value and denotes the first disappointment to inexperience in qualitative data analysis.

5 Results

In this section I will present the results of the analysis. The results are presented in graphs and tables. I will begin by explaining how to interpret the graphs and then present my findings. Finally, I will summarize my findings with respect to each research question in table 6.2.

5.1 Interpreting the Graphs

Two kinds of graphs are presented in this chapter. One of them illustrates the domain of teacher discourse ($S, O, I/O, I$) with respect to the phases of practical activities (E0, E1, E2, E3) and the other one the form of classroom interaction (1-9) with respect to the domain of discourse. On the horizontal axis in all the graphs is class time starting form when the lesson begins and ending when the teaching ends. In half the lessons the latter meant students packing away their books and leaving the classroom and in the other half it meant that time from the end of the lesson was used for filling out a questionnaire related to the data accumulation (however, the data from these questionnaires is not in any way connected to this thesis). In each graph one of the parameters is shown on the vertical axis and the other one is color coded. The legends for interpreting the color codes are shown in the graphs. Furthermore, simplified



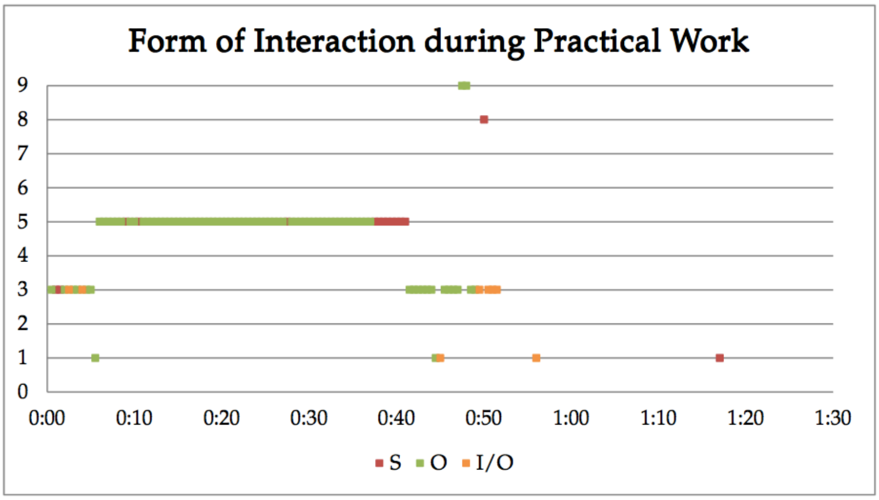
Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 3: **The domain of teacher discourse illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right (for the complete definitions, see table 4, and the text for clarification on the categorisations).**

definitions for the phases of practical activities and the form of classroom interaction are shown on the right side of the graphs; for the full descriptions, see tables 4 and 3. A few of these graphs are presented here as examples for interpretation. However, all graphs can be found in appendices B and C.

In figure 3 the vertical axis shows the domain of teacher discourse with *S* for silence starting from the bottom and continuing as *O* for discourse in the domain of objects and observables, *I*/*O* for discourse making links between the domain of ideas and the domain of object and observables, and *I* for discourse in the domain of ideas. The color coding represents the phases of practical work so that E0 stands for no practical activity and E1-E3 for introduction, experimental and discussion phases of the task (as described in table 4).

In figure 4 the vertical axis represents the form of classroom interaction as categorized in table 3. As mentioned previously in chapter 4.3, only interactions during practical work are shown in the graph; although interactions during non-practical work have also been analysed, they are excluded from



Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 4: **The forms of interaction in class during practical work illustrated as function of class time as shown in the table on the right (for the complete definitions, see table 3). The color coding represents the domain of teacher discourse (see text for clarification on the categorisations).**

the graphs for the sake of clarity. The domain of teacher discourse is color coded. It should be noted that in the Domain of Teacher Discourse-graphs (represented by figure 3) the domain of teacher discourse is on the vertical axis and in the Form of Interaction during Practical Work-graphs (represented by figure 4) it is color coded.

5.2 Findings

In this section I will present my findings on a general level instead of going through all the lessons systematically. I selected this approach because observations from most lessons were quite similar in many respects. However, there were deviations in the data and they, too, will be presented and analysed.

The lessons are identified by the teacher number as coded in the original data (10, 12, 20 and 24). The two two-lesson sequences that were not double lessons are identified 20:1 and 24:1 for the first lesson, and 20:2 and 24:2 for the second one, respectively. The double lessons are simply referred to by the teacher number 10 and 12, respectively.

When drawing the graphs on the domain of teacher discourse one noticed the lack of discourse in the domain I during practical work: only one 1-minute period of was included in the eight lessons. This scarcity can also be seen in tables 6 and 7. However, it must be clarified that there was discourse in the domain of ideas during the lessons, but for the most part it happened during non-practical work (which is excluded from the tables).

There was some discourse in the domain I/O during practical work in all the lessons that involved student work. Furthermore, discourse in the domain I/O was not characteristically tied to practical or non-practical activities: there was some in all sorts of activities as can be seen in graphs illustrating the domain of teacher discourse (Appendix B). However, the amounts of time used on discourse in domain I/O were not long as can be seen in table 6.

Table 6: **The amounts of time used for discourse in domains I/O and I during practical work. The times are presented in minutes and seconds.**

Domain	Lesson 10	Lesson 12	Lesson 20:1	Lesson 20:2	Lesson 24:1
I	0:00	0:00	1:00	0:00	0:00
I/O	4:30	4:00	2:00	0:00	0:30

The graphs on the form of classroom interaction (Appendix C) show how discourse in domains I and I/O is focused on teacher lectures and whole class discussion. Only one teacher had a conversation with one student namely during practical work when the majority of class were returning the equipment after a practical task (see figure 13). The most common forms of interaction during practical work were pair and group work. This is hardly surprising as the practical activities were student work, apart from lesson 20:2 where the activity was a demonstration. Equally predictably, class discussion and lecture by the teacher share the status of the second most common classroom interaction during practical work.

As shown in table 7, the majority of class discourse during practical work (apart from one exception over 90%) was in the domain O. The exception in lesson 20:1 was not, in the author's opinion, due to a particularly large amount of discourse outside the domain O, but was caused by the very short length of the practical activity in question: as can be seen in figure 7, the whole practical activity from introduction to the end of discussion lasted less than ten minutes and the part where the discussion was outside domain O lasted three minutes. Furthermore, out of these three minutes 1.5 were used for the discussion with a single student mentioned in the previous chapter. Thus one feels that, as it represents a very small portion of the sample, this deviant result can be overseen and it can be stated that in the light of the data, a gross majority of the discourse during practical work is in the domain of objects and observables (O).

Table 7: **The percentages of classroom discourse in the domains O, I/O and I during practical work. Discourse in the domain S has been substracted from the data before calculating these results.**

Domain	Lesson 10	Lesson 12	Lesson 20:1	Lesson 20:2	Lesson 24:1
I	0	0	11	0	0
I/O	7	9	22	0	3
O	93	92	67	100	97

As can be seen in table 8, in five out of seven lessons the majority of the discourse in domains I/O and I happens during the discussion phase of the practical activity. Again, the deviant results can be explained through the quality of the data. As explained in the previous paragraph, 1.5 of the three minutes of discourse in the domains of interest happened between the teacher and one student while the other students were returning the equipment. However, this is not a basis to dismiss the result: the discussion was relevant and the categorisation was done precisely according to the used categorization systems, and due to the small number of data points it is not justified to count this to be a statistical anomaly.

The other deviation in lesson 24:1 is caused by the fact that during the entire lesson there was only one thirty-second period when there was discourse in the domains of interest during practical work. Surely it could safely be argued that this is such a small portion, only a single specimen in a pool of tens, that it could be overlooked to make a coherent statement about the issue of the domain of discourse and the phase of the practical activity (as was done in the case of the discourse in the domain I in the penultimate paragraph). However, in the light of the deviation described above one feels that it cannot be justified to make such a statement. Nevertheless, one may comment that the results indicate that the discourse in domains I/O and I during practical work would be focused in the discussion phase of the activity, but to make a well-justified statement, further research and more data would be required.

Table 8: **The percentages of discourse in domains I/O or I during practical work with respect to the phase of the practical activity.**

Phase	Lesson 10	Lesson 12	Lesson 20:1	Lesson 20:2	Lesson 24:1
E1	0	0	0	0	100
E2	11	0	50	0	0
E3	89	100	50	100	0

6 Discussion

In this chapter I will present answers to the research questions (from now on denoted simply by RQ) based on the findings of this study and critically evaluate them in the light of relevant literature. I will also present and reflect on some thoughts arising from the study not directly connected to the research questions. Finally I will suggest topics for future research, improvements on the method of analysis and implications with respect to teacher training and teaching materials in the light of this study. However, I shall start this chapter with a few words on the quality of this work.

6.1 Quality

I will base the reflection of the quality of this work on the standards by Miles and Huberman. These include the objectivity and confirmability, the reliability and dependability, the internal and external validity, and the utilization and application of this work [1994:277–280].

Objectivity in this work has been pursued by being concious of any factors that may affect processes of analysing the data and drawing conclusions from the results, and eliminating such biased views. Examples of these are the effects of reading studies on the same subject as one is researching. Furthermore, all the aspects of this study are described with care to ensure good confirmability.

Steps have also been taken to ensure the reliability and dependability of this work. Research questions were posed clearly and the design of the analysis was based on them. The process of collecting the data was done using good research practices and by experienced and respectable professionals. The reliability of coding the raw data was checked by comparing the data coded by the author to that done by a second coder. Finally, it can be said that the findings of this study are in line with previous research.

Internal validation, or the "truth value" [Miles and Huberman, 1994:278] of this work was evaluated by simply reflecting the results in the light of everyday classroom practices and related literature. The question of external validity of this work i.e. whether these results and conclusions may be generalized was the hardest one to answer here as the author was not provided with any information of the schools where the data was collected. However, the author could see from the video recorded lessons that the sample schools were diverse in class size and funding, and that there were teachers both young and experienced. Thus it could be suggested that the sample is rather heterogeneous and that no apparent reasons for a lack of generalizability are found other than those that are explicitly indicated in the discussion.

Finally, the utilization and application of this work is pursued by keeping the discussion related to the classrooms and everyday teaching; high-flown rhetoric is kept to the minimum. Furthermore, future research and possible actions with respect to teacher training and teaching materials are briefly suggested in chapter 6.3.

6.2 Answers to the Research Questions and Reflection

The purpose of RQ 1 was to find out whether there is any discourse purely in the domain *I*, that is with no connections to the practical level, during practical work. The answer is that there was virtually no such discourse observed in this study. This is hardly surprising when considered from the everyday point of view of a physics lesson: it would seem to make little sense to talk about phenomena purely in the domain of ideas during a practical task, especially in the light of the purpose of practical work presented in figure 2 (making links between domains *O* and *I*). However, the results show that there is some discourse purely in the domain of ideas during lessons, only it is concentrated around non-practical activities.

RQ 2, are connections being made between the domain of objects and observables and the domain of ideas during practical work, was the most important one in the framework of this study. Quite pleasingly it was found that indeed these connections are made, however unfortunately the amounts of time used for this sort of discourse are not that impressive across the board: as shown in table 6 they vary a lot. Nevertheless, when comparing these results to those of Abrahams and Millar [2008] one may cautiously suggest that the results seem to indicate towards Finnish teachers making a little more links to the domain of ideas during practical work. Abrahams and Millar found that 20 out of 25 science teachers used no time at all to discuss the ideas or models to be used during practical work and in this study only one out of five did so (table 6). However, to make well-justified statements the sample should involve a lot more teachers.

Nevertheless, one observation can be made from the data: although the amounts of discourse in domain I/O were not impressive, at least most of the students seemed to be aware of the ideas they were intended to use during the practical work. This was observed in the videos as the teachers actively engaged the students to answer questions about the practical work and the students being able to answer them as illustrated by this extract (from Appendix A):

> **Teacher 24**: What do you need to measure [to determine the power of a light bulb]?
>
> **John**: Voltage and electrical current.
>
> **Teacher 24**: Yes, so you'll need both meters.

Although this does not necessarily implicate that all the students had understood the purpose and content of the practical activity with respect to the theory and/or vice versa, it suggests that they were familiar, at least on the conceptual level, with the ideas the teacher intended them to use. I consider this a positive observation compared to that made by Abrahams and Millar:"... in many of the tasks observed, the students appeared unfamiliar with the ideas that the teacher intended them to use" [2008:1956].

The question-answer-type of discourse illustrated in the extract above was quite common in the lessons analysed. When doing the form of class interaction-categorisation these were the most difficult parts to classify. There is a fine line between teacher lecturing with occasional questions to students and class discourse. The used categorisation system states that "When the teacher's main goal is the transfer of knowledge, then code 'lecture by teacher"' [Seidel, 2005:81]. However, quite often the knowledge transfer from the teacher to the students was preceded by first probing the correct information from the class in an Initiation-Response-Evaluation-type of exchange (for reading on IRE-patterns, see for instance Mortimer and Scott 2003). There was very little 'traditional' lecturing in the form of teacher monologue. Should one use this classification in the future, this issue would have to be clarified to ensure better results.

The purpose of RQ 3 was to quantify how much of the discourse in class is related to the domain *O*. The answer is that a gross majority of discourse during practical work is in this domain. This finding is in line with that of Abrahams and Millar: "The overwhelming sense, from the set of lessons observed, was that a high priority for teachers is ensuring that the majority of students can produce the intended phenomenon, and collect the intended data" [2008:1955]. Granted, discourse in the domain *O* is necessary so that the students are able to successfully complete the tasks, and it is quite difficult to say how much of it is needed.

However, there were instances in the lessons examined where clear opportunities to discuss the ideas behind the practical activities presented themselves and the teacher overlooked them. For example in lesson 24:1 the students had to draw a schematic diagram of the circuit they were going to use to determine the power of a light bulb. The idea was to measure the electrical current in the circuit and the potential difference (voltage) across the bulb, but repeatedly the students kept offering to connect the voltmeter parallel to the battery in the circuit. However, the teacher did not attempt to get the students to think about how the meter should have been connected and why it was so, but only said that it was connected incorrectly.

RQ 4 is probably the most interesting one with respect to everyday teaching. The effect of the nature of activities in class to the domain of discourse is directly connected to classroom practices. Unfortunately in the case of the phases of practical activities the results were inconclusive: there were implications of the discussion phase being the one where most connections are made between the domains *I* and *O*, but the results between different lessons were not coherent enough to make a valid argument. Having said that, this result does point towards the same direction as the study by Tiberghien [1999] presented in chapter 2.2 which showed that most connections between the theoretical models and the tangible objects and events were made during the discussion phase of practical work.

Studying the forms of classroom interaction during practical work did, however, produce an unambiguous result: the discourse in domains I and I/O was focused almost exclusively on teacher lecturing and class discussion. Only one example of a discussion between a teacher and a student was included in the data. When the teachers were circling in the class during the practical activities, their attention was solely in helping the students get their wirings right and help the students get the results even though there were plenty of opportunities to discuss ideas, like the one described penultimate paragraph.

The above observation gives rise to the question whether the teachers meant for the students to be actively engaged in the task with their minds as well as their hands, and if yes, why was there no evidence of this. Unfortunately these questions cannot be answered since teacher interviews were not included in the data, but it would seem reasonable for the teachers to want their students to think about what they are doing instead of just doing it. Of course the students could be actively engaged to the tasks with their minds without the teacher prompting them, but as can be seen in the graphs in Appendix B, the activities typically went on for more than ten minutes without the teacher stepping in to provoke link-making to domain I. This is all, however, speculation, and further research is required to be able to give any well-justified statements on the matter.

6.3 Future Research, Improvements to the Research Method and Implications with respect to Teacher Training and Teaching Materials

Some implications for future research and improvements to the method have already been proposed, but them and a few more will be explicitly presented here. Also implications with respect to teacher training, applying to both preservice and in-service training, and to teaching materials are mentioned.

After completing this work ideas for possible improvements to all parts of the analysis have arisen. First of all, the categorisation of discourse could do with a fifth classification which includes numerical and mathematical discourse. One felt that this sort of exchange was difficult to categorise, since making calculations is one way of applying theory and models, but still the discourse during these calculations most often had to do with the mechanical repetition of writing down figures and typing them to a calculator. Amusingly enough, this view is shared by Helaakoski and Viiri [2014], who worked on the QuIP study (from which the data for this work is). Actually, the analysis in the frequently mentioned study by Tiberghien [1999] had a separate classification for numerical models and although the author of this thesis did not seize upon it when designing the analysis she sees the point now.

The analysis of the nature of activity in class should be done in shorter intervals than thirty seconds. When designing the analysis the author felt that it would be convenient and sufficient to match the interval with that of the teacher discourse analysis, and for the purpose of producing the framework of the teacher discourse it was so. However, as the work went on the author started to feel that the relationship between the domain of teacher discourse and the nature of activity in class was the most interesting aspect of the study and thus now feels that more nuances of this relationship could have be extracted from the data should it have been done with intervals of for instance 10 or 15 seconds.

Furthermore, one feels that the categorisation of the form of interaction could do with a few modifications. Again, after completing the analysis the author found that the same alterations that had come to her mind while doing the categorisations had also been applied in the QuIP study [Beerenwinkel and Börlin, 2014]. Referring to table 3, form of interaction 2 (dictation) could be extended to also include students taking notes from the whiteboard of overhead projector. Form 3 (class discussion/class work) could be transformed to "teacher-centered classroom discussion". This would reflect the nature of the discussion better. Finally, the minimum length of a period to be qualified as form 1 (teacher lecture) could be expanded to 60 seconds or so. This probably would help with the difficulty of categorising question-answer type of discourse described in the previous chapter (6.2).

The author's interests concerning future research remain close to the topic of practical work and its efficient implementation in the classroom. A logical step onwards from this study would be to study student discourse during practical work to see if students are indeed handling phenomena in the domain of ideas *I*. After acquiring this information one could plan and implement a short training program for teachers and/or student-teachers to more efficiently make links to the domain of ideas instructing students on practical work, and study the effects of this intervention.

The consequence of this study with respect to teacher education and in-service training should be rather clear at this point: teachers and teachers-to-be should be prompted to reflect on the importance of making links between the domains *O* and *I* during practical work and given tools to provoke the making of such links. The study showed that these sorts of connections are being made, but their amount varied widely, which implicated that not all teachers are aware of its significance. Furthermore, one would also wish to see these links being made during the physically active phase of practical work when the students are working in pairs or small groups. In fact the author thinks that this is the area where most potential for development lies. However, to be able to instruct teachers in these matters, a study like the one described in the previous paragraph should be executed.

Another interesting and important area to look into are teaching materials and especially what sort of questions do the practical tasks therein contain and how are teachers guided on the instruction of practical work in the teaching manuals. In the frequently mentioned study by Tiberghien [1999] it was found that the key to get the students to discuss the ideas behind the phenomena i.e. to make links between domains *I* and *O* was to give them tasks to reflect on the experiment. Furthermore, in the study by Abrahams and Millar it was found that a majority of teachers observed in the study did not plan their own practicals, but followed a commercially produced scheme of work.

They experienced their own role mainly as "'delivering' an activity judged appropriate by others" [2008:1954]. These results reflect the responsibility the authors and publishers of teaching materials have with respect to successful implementation of practical work in schools. However, to produce better materials, further research on how practical work is presented in textbooks and teaching manuals now and how it should be presented in the future to produce the best possible results.

Appendices

A Practical examples on how to categorize discourse

Table 9: **These excerpts are extracted from the data and translated from Finnish by the author. They are chosen to represent discourse typical for the examined lessons which is why descriptions are included as well. The names of students have been replaced by English names with matching gender. Student discourse is shown in brackets.**

Domain	Description	Excerpt
S	Teacher is silent while students copy down notes from a transparency, make measurements or do calculations independently	–
	Lesson practicalities: Initiating or ending class, checking who is absent or giving homework	"Alright, good morning, please to be seated. Who sit next to Lucy? Alice and Emily? Have they been absent since the beginning of the school day?"
	Presenting the propagation of the lesson (school day/period/etcetera	"I thought that today we would not have a normal break as discussed, but only a small one in case someone needs to use the bathroom or something."
O	Introduce a phenomenon, an object or an observable.	"What happened when you increased the voltage in the toy engine? [Philip: well, it spun harder]. Yes, it spun harder, right? It spun faster."

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	Presenting equipment or how to use them	“What do you think, what equipment do you need for this work? What do you need first of all? John? [John: a battery]. Yes, we’ll need a power supply or a battery. Use these yellow ones, they are fresh.”
	Discussing the symbol or unit of a physical quantity	“What is the unit of power? Who should I ask, I’ll ask George. [George: P] Oh, you said P, you’re mixing up two things. What is P? It’s not the unit, but? William? [William: symbol]. It is the symbol.”
	Presenting a calculation	“First we’ll write down the formula, P equals U times I. What do we write down as U? John? [John: 230 volts]. And as I? Cathy? [Cathy: 5 amperes]. Now you can calculate the power.”
I/O	Applying theoretical knowledge on the practical level	“What do you need to measure (to determine the power of a light bulb)? [John: Voltage and electrical current]. Yes, so you’ll need both meters.”

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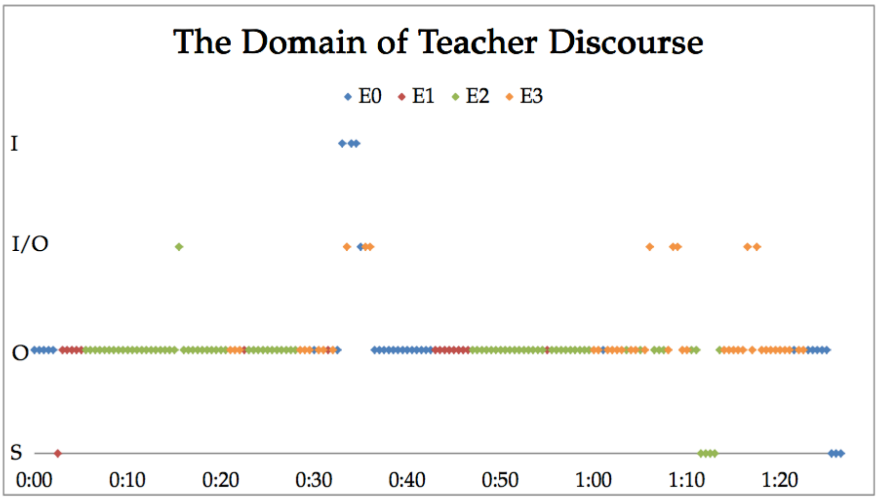
	Using practical observations to illustrate theoretical knowledge	"If these four components that you have examined would be operated on a battery, which component would function longest? [Harry: LED]. That's right, good effort. Why is that? ... So its power is the smallest one.
I	Present a relationship	"What does energy consumption depend on? ... Energy consumption depends on the power of the device... yes, it depends on the power, but then there's something else as well? [Jonathan: time]. Yes, time."

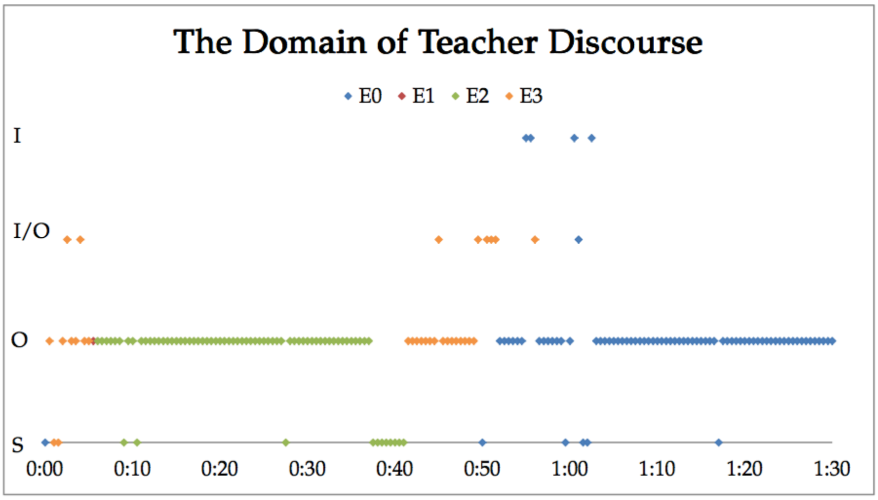
B Graphs illustrating the Domain of Teacher Discourse during the Lesson

The graphs in this appendix illustrate the domain of teacher discourse during the lessons as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table to the right of each graph. See table 4 for the complete definitions for the phases of practical work and chapter 5.1 for further instructions on how to interpret the graphs.



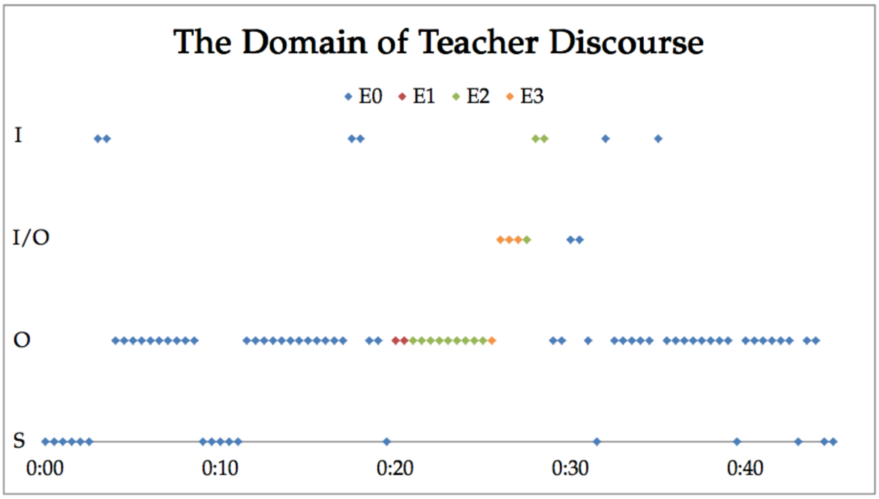
Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 5: **The domain of teacher discourse during lesson 10 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**



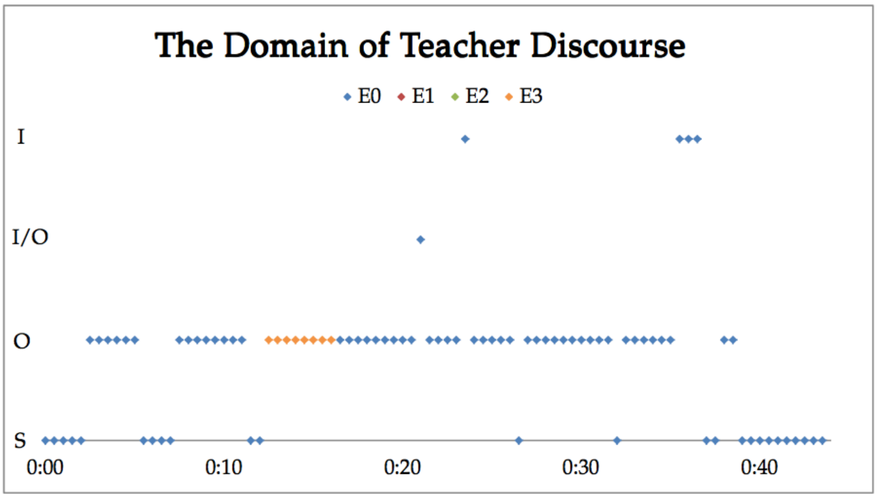
Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 6: **The domain of teacher discourse during lesson 12 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**



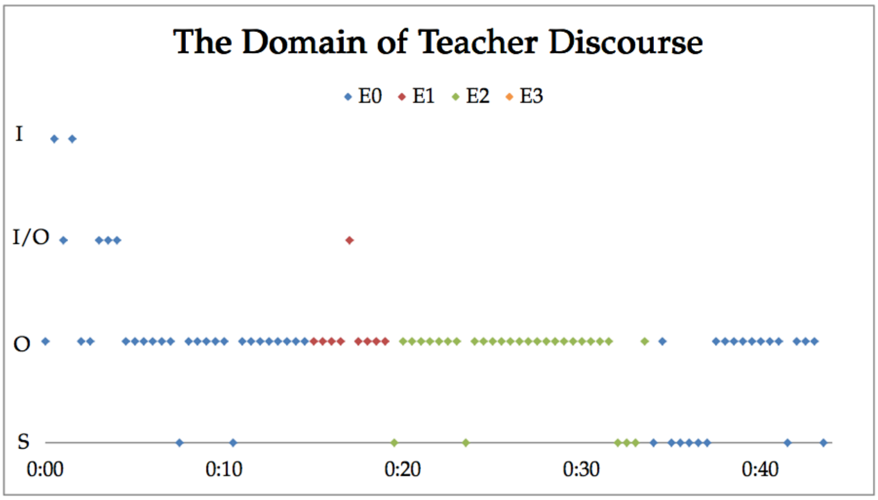
Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 7: **The domain of teacher discourse during lesson 20:1 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**



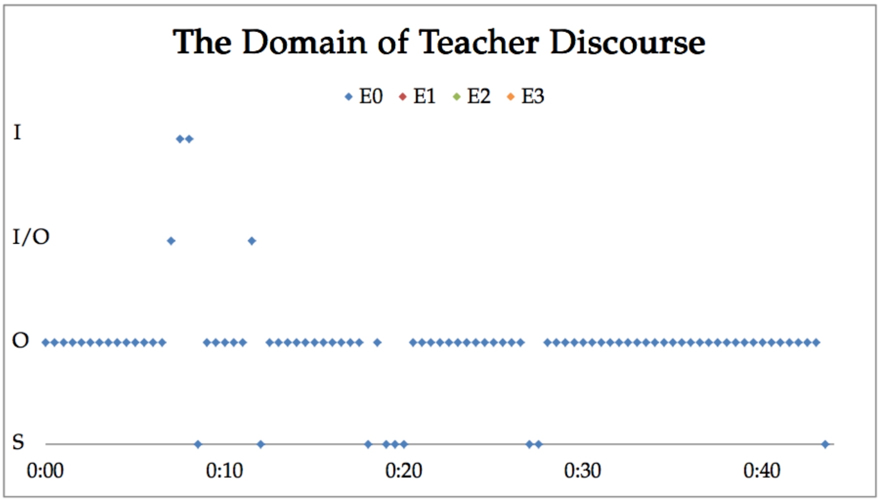
Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 8: **The domain of teacher discourse during lesson 20:2 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**



Label	Phase
E0	None
E1	Intro-duction
E2	Activity
E3	Discus-sion

Figure 9: **The domain of teacher discourse during lesson 24:1 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**

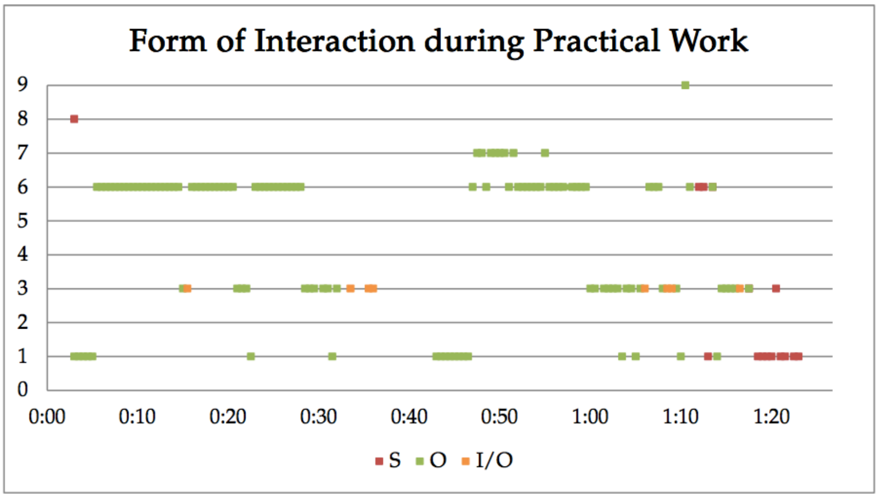


Label	Phase
E0	None
E1	Introduction
E2	Activity
E3	Discussion

Figure 10: **The domain of teacher discourse during lesson 24:2 illustrated as function of class time (shown in hours and minutes). The color coding represents the phases of the practical activities as shown in the table on the right.**

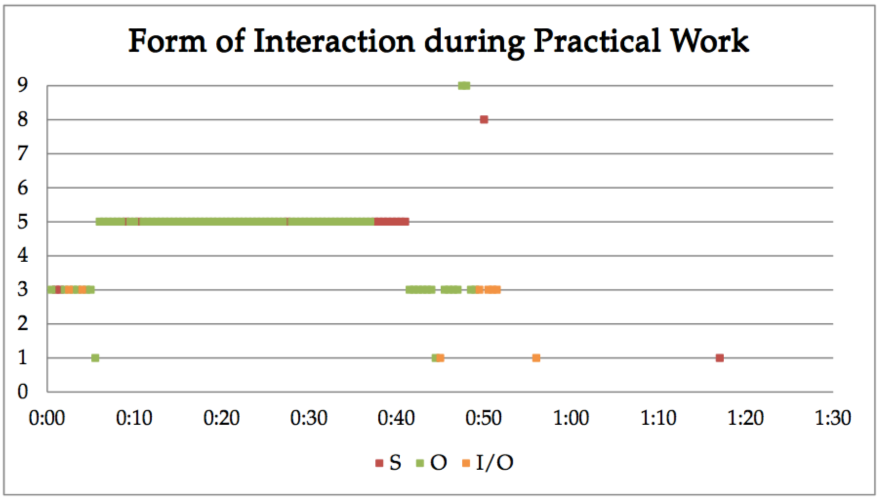
C Graphs illustrating the Form of Interaction during Practical Work

The graphs in this appendix illustrate the forms of interaction in class during practical work as function of class time as shown in the table on the right of the graphs. The color coding represents the domain of teacher discourse. No graph is shown for lesson 24:2 because the lesson contained no practical work. See table 3 for the complete definitions for the forms of classroom interaction and chapter 5.1 for further instructions on how to interpret the graphs.



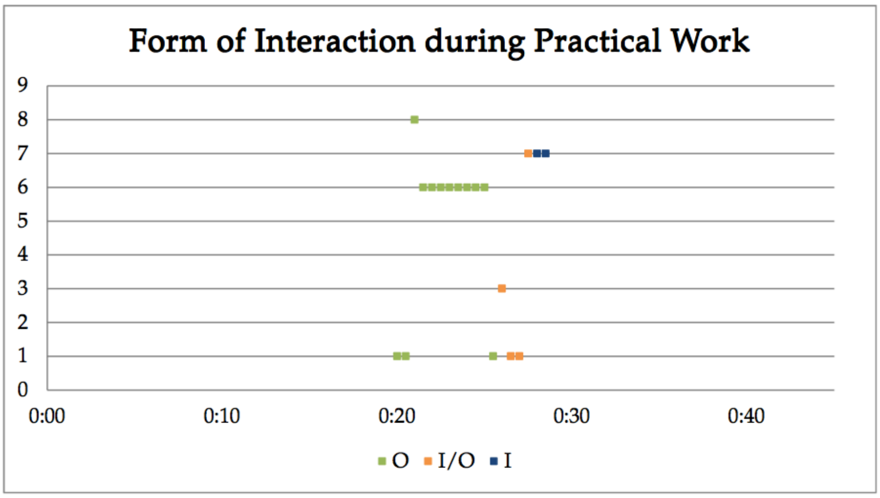
Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 11: **The forms of interaction in class during practical work in lesson 10 illustrated as function of class time as shown in the table on the right. The color coding represents the domain of teacher discourse.**



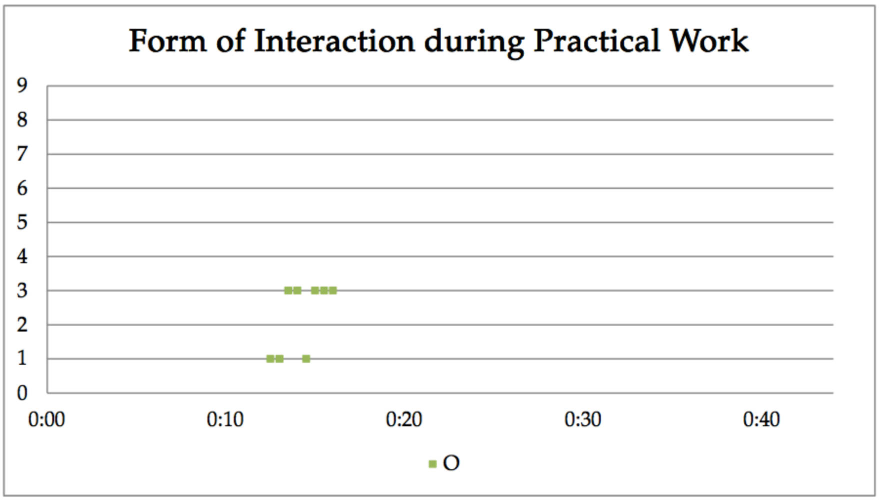
Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 12: **The forms of interaction in class during practical work in lesson 12 illustrated as function of class time as shown in the table on the right. The color coding represents the domain of teacher discourse.**



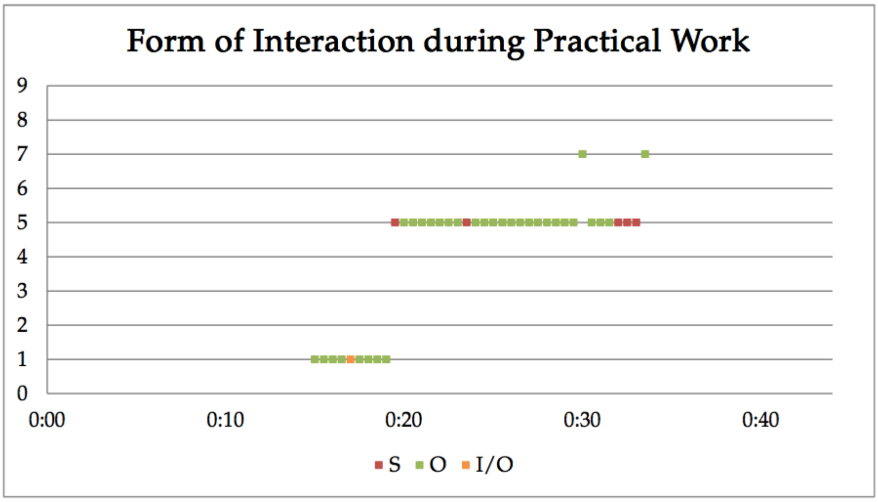
Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 13: **The forms of interaction in class during practical work in lesson 20:1 illustrated as function of class time as shown in the table on the right. The color coding represents the domain of teacher discourse.**



Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 14: **The forms of interaction in class during practical work in lesson 20:2 illustrated as function of class time as shown in the table on the right. The color coding represents the domain of teacher discourse.**



Label	Interaction
9	Other
8	Transition
7	Several interactions
6	Group work
5	Work in pairs
4	Individual work
3	Class discussion
2	Dictation
1	Lecture
0	None

Figure 15: **The forms of interaction in class during practical work in lesson 24:1 illustrated as function of class time as shown in the table on the right). The color coding represents the domain of teacher discourse.**

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