

# Lab-reports as a base for learning through writing in scientific genres – from an empirical perspective

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## Abstract

Insight into students' writing of lab-reports viewed from the perspective of genres might provide useful information about the learning potential of practical work and of writing in science. In this study, therefore, we set out to explore students' use of argumentation and scientific genres in their lab-reports. In order to study the impact of teacher's guidelines on the presence of argumentation and genres we also analysed the purpose and requirements communicated the teachers.

The analyses of the seventeen lab-reports we based on Toulmin's concept of argument, but also on Martin's identification of scientific genres. We found that most reports included only one or two arguments, and in half of the reports observations was used not to support a hypothesis but to illustrate a scientific theory. We found that many students used a mixture of two genres, *experimental report* and *scientific explanation* in their lab-reports. Moreover, this mixture was consistent with the requirements communicated by the teacher. In lab-reports containing hypotheses, methodological reflections and arguments based on scientific theory were rare.

We conclude that although the teachers wanted to make requirements facilitating learning, their requirements resulted in lab-reports which deviated in several respects from scientific experimental reports. In addition, they involved an insufficient implicit view of the nature of science. We hypothesize that students' learning from writing lab-reports will be improved if teachers combine an increased understanding of *experiment* and *explanation* as scientific genres with the inclusion of scientific argumentation as a requirement for lab-reports.

## Introduction

Several authors have argued that making scientific arguments can facilitate pupils' comprehension of scientific theory and of the nature of science (e.g. Driver, Newton & Osborne 2000; Martin, 1993). Moreover, scientific literacy needs to include ability to interpret text written in scientific genres that they might meet as future citizens. Scientific genres include reports from experiments, which basically provides arguments for a hypothesis put forward. However, there are indications in the literature (Newton, Driver & Osborne 1999) that scientific argumentation do not occur frequently in school science. How then, might we facilitate student's use of argumentation in science? Fang (2005) provides one answers, and argues that writing research reports based on own scientific experiments will promote students argumentation, and students' science learning through argumentation. However, empirical insight into students' use of genres and argumentation in their lab-reports are weak. Thus, this study set out to inquire the following three questions:

- 1. To what extent do the students include argumentation in their lab-reports?**
- 2. What characterises their use of arguments and genres in this context?**
- 3. How can we understand these characteristics in light of the teacher's demands for a good lab-report?**

The underlying hypotheses are that lacking focus on argumentation in lab-reports is an important reason for the view held by many science teachers, that practical work is not very effective for learning science. Moreover, we believe that focusing on argumentation in students' lab-reports will increase their ability to read and understand professional scientists' argumentation and reports from experiments. In a society where socioscientific issues are present everywhere, such ability is important for democratic participation and citizenship. Insight into the interplay between teachers demands and argumentation and genres in students lab-reports can support the development of better guidelines for how to teach the writing (and reading) of lab-reports.

## **Inquiry learning**

The focus on argumentation in students' lab-reports is based on Dewey (1913) concept of learning by doing and a constructivist view of the nature of science. Dewey (1913) emphasised that "doing", or an "activity", do not by itself constitute an experience. An experience is an expectation about the consequences of actions: what will happen if I do this? In order to establish an idea about the possible link between action and consequence, the learner needs to reflect on the relationship between these. Thus the learner needs to reflect, or think as Dewey phrased it, and this reflection need to be focused on the changes brought by the action. Consequently, Dewey states that an experience is a hypothesis, or a claim, about a connection in the world. Moreover, this hypothesis is backed by the experienced and observed actions and consequences. Without this kind of reflection and generation of hypothesis, a practical learning activity will involve doing but not learning.

When working with experiments in science teaching, the lab-report provides one relevant area for stimulating students' reflections. However, if the hypotheses students make are to be scientific hypotheses (and thus involve learning science), students need to look at their observations and ask "Why?", and construct hypotheses (and thus also identify entities involved in the phenomena) that use their observations as evidence. In principle, this is no different from professional scientific inquiry where hypotheses are proposed and observations are used as evidence to back up the hypotheses.

In school science, students might be given open-ended tasks, where the students themselves are supposed to generate tentative explanatory hypotheses. However, more typically, students are given closed or structured tasks, and the natural phenomena and the experiments conducted are already explained by established scientific theory. This is one of the reasons why practical work often is done as "verification experiments" where the goal is to show or explain how observations are consistent with scientific theory. The kind of argumentation students do, or are supposed to do in their lab-reports might depend on the kind of tasks they have worked on. In this study structured practical tasks is in focus.

An assumption underlying this study is that the hypotheses or theories to be learned from practical work in science are not contained in the observations the students make. This is a central tenet in constructivist accounts of science (Cole, 1992; Latour, 1987; Ziman, 1968). Theoretical entities and descriptions are constructed by humans. In principle, different theories might be constructed which accounts for the same phenomena (Quine, 1961). Moreover, to give meaning, observations need to be interpreted in light of theoretical entities (Kuhn, 1962). Consequently, theories cannot be "seen" in data or interpreted from data. To establish a link between observations and theory the observations needs to be interpreted, and several theories or hypotheses might be relevant to examine.

For practical work in science education, this view implies that it is not enough to make the students do observations and record these systematically. If the aim is to learn scientific

theory or scientific ways of thinking, the students must try to interpret their observations. This interpretation can be based on their own hypotheses or established scientific theory. Explaining or defending such interpretations implies using observations as supporting evidence for a theoretical position. Thus, the process of communicating interpretations involves argumentation.

In sum, Dewey claims, in his theory of learning, actions and observations need to be consciously connected through reflection about relationships to generate experience or tentative theory about the world. Constructivist views of the nature of science states that the development of scientific theory involves reflections involving interpretation of observations based on tentative theories. Thus, this view of how scientists learn about the nature supports and deepens Dewey’s view of how humans learn from “doing”. The constructivist view of science explains that hypotheses about empirical connections need to be applied or constructed to give meaning to observations. Thus, scientific observations are not different from Dewey’s action-based observations in this respect. Science students need to make connections between observations and scientific theory if they shall generate a deeper understanding of the *experiences* we denote as scientific theories. This view implies that to learn science through practical work, students need to be stimulated to make reflections involving scientific argumentation, e.g. through communicating their interpretations in a lab-report.

## Scientific argumentation

In the analysis of the lab-reports, a simplified version of Toulmin’s concept of arguments where used. Toulmin (1958) defines arguments as claims supported by a justification. The role of a justification in an argument is to underpin the claim put forward. According to Toulmin (1958), such justifications involve the use of data or “facts”. In Toulmin’s layout of arguments, data is a generic term which refers to all kinds of evidence that might be used by an arguer to support a claim. In support of factual and causal claims, factual evidence involving empirical or theoretical statements is often used (Wood, 2000).

In the first stage of the analysis of the lab-reports, we discovered the presence of arguments which did not consist of a hypothesis backed by observational evidence. Thus we defined scientific arguments in general as arguments where the claim and the data where claims about nature, and which involved either observations/measurements or established scientific theory. Consequently, in a scientific argument, the claim might be a hypothesis, an established theory or an observation. The data, or “facts” used in the justification, are often observations, but might also be a scientific theory. However, we do not regard it as relevant to use a tentative hypothesis as data. Consequently, we can define four types of scientific argumentation (see table 1). Not all these types of arguments were identified at this stage of the analysis. The general types were identified in order to make a more nuanced analysis of arguments in the lab-reports (Eneroth, 1984; Strauss & Corbin, 1990).

**Table 1:** *Types of scientific arguments. Scientific criteria for judging the claims are given in the parenthesis.*

Data ↓ Claim →	Observations	Hypothesis	Theory
<b>Observations</b>	X	Empirical argument H (empirical consistency)	Empirical argument T (empirical consistency)
<b>Theory</b>	Explanatory argument (consistency)	Theoretical argument (theoretical consistency)	X

The types of arguments given in table 1 was given the following definitions:

Empirical hypothetical argument: A hypothesis is proposed and observations are used as data to support the hypothesis. The following is an example from one of the lab-reports. Here the connection between the hypothesis (that the length of the pendulum determines the swing time) and the observations (list of measurements) are not stated explicitly, but is implicitly included:

*Results: [lists of measurements]. Conclusion: It was the length of the pendulum that determined how many seconds it took.*

Empirical theoretical argument: An established theory is stated and supporting observations are presented. This might not be a common type of argument, as the presentation of evidence for a theory involves treating it as a hypothesis and not as a theory. However, in pedagogical contexts one might find instances where the correctness of an established scientific theory is backed by presenting confirming evidence. However, as Popper pointed out, a limited set of observations cannot logically establish the validity of a general theory. We found none examples of this type of argument in the seventeen lab-reports.

Explanatory arguments: In this type of argument, the observation is what is claimed, and a theory is presented to justify the correctness of an observation. It might seem strange to state that a theory justifies an observation. However, scientific theory can in principle change our view of what is observed, e.g. the distances between the stars as seen with our eyes versus the scientific measurements of distances based on their distribution in a three dimensional space. Moreover, the point here is not the trustworthiness of an observation, but the logical relationship between a claim and a justification, e.g.:

*Result: The water is heated until it boils. There are a lot of movements in the water and it squirts out of the glass pipe going through the cork, because the particles need more space.*

Here the observation (water squirts out of the glass pipe) is explained by showing how it is justified by, and consistent with, established scientific theory. This kind of arguments occurs in explanations of scientific phenomena.

Theoretical argument: In this type of argument, a hypothesis is stated, and the hypotheses is justified or attacked by pointing to its consistency or inconsistency with established scientific theory (Kuhn, 1977). We found no attempt to make this kind of arguments in the seventeen lab-reports.

Methodological arguments: In reports from experiments the method used is supposed to be described and sometimes even invented by the students. When a methodological choice or step is claimed to be advisable or unwise and this claim is backed by a justification, this constitutes an argument. Thus, we defined methodological arguments as a fifth type of argument. *Eg. "We did ... in order to avoid/ensure ...."*

## Scientific genres

The analysis of genres used in the lab-reports was based on Martins (1993) conceptions of scientific genres. According to Latour (1987) and Martin (1993), the purpose of a scientific research report is to persuade the reader, or the scientific community, about the reliability of a scientific claim put forward. To meet this purpose, the writer of empirical papers makes use of arguments where observations and measurements, in addition to theoretical ideas, are used to underpin the claim being made. The most typical scientific research report uses the **IMRaD** structure, which is defined as consisting of the four sections **I**ntroduction, **M**ethod, **R**esults and **D**iscussion.

However, lab-reports made in school science do not necessarily mimic professional scientists' research reports. In addition, text with scientific content occurs in different types of genres. Martin (1993) has identified *experiment* (research report), *report* (textbooks), *explanation*, *exposition* and *bibliography* as traditional scientific genres. Moreover, he states that genres might be understood as "staged, goal-oriented, purposeful" texts (Martin, 1984, p. 25). Accordingly, the genre or kind of text pupils uses in their lab-reports will partly depend on their understanding of the social purpose of their writings. A basic idea in this study, therefore, is that there might be an important interplay between the students' writings and the purpose and requirements communicated by the teacher. Moreover, insight into students' writing viewed from the perspective of genres might provide useful information about the learning potential of writing in science.

### **Methods and Samples**

In this study we explored pupils' use of argumentation and scientific genres in their lab-reports. In order to study the impact of teacher's guidelines on the presence of argumentation and genres we also analysed the purpose and requirements of lab-reports communicated to the pupils by their teachers. Lab-reports were gathered from teachers in two lower secondary science classes in a school outside a town at the west-coast of Norway. Data included seventeen lab-reports (to be extended) from structured hands-on experiments. The two science teachers involved were interviewed about the requirements and purposes communicated to their pupils concerning their writing of reports from hands-on experiments. In addition, documents about requirements handed to the pupils were collected.

The two teachers were selected on the basis that they used closed experiments with recipes to be followed by the pupils. The study is embedded in a larger study focusing on what differences could be found, regarding presence of scientific argumentation, between pupils' reports given different requirements communicated by their teachers.

### **Requirements**

In the analysis of the interviews and the documents with the teachers' requirements, we focused on the following: 1. Types of experiments used (open ended vs. closed, degrees of freedom, structured vs. unstructured). 2. Requirements about structure and content. 3. Social purpose (who is the factual and imagined readers and how will readers use the report). 4. The kind of insights hoped to be acquired by the pupils during the activities related to the experiment (scientific theory, conceptual understanding, nature of science, scientific argumentation or other).

### **Identification of arguments**

To enable the identification of arguments we used a simplified version of Toulmin's (1958) layout of arguments, focusing only on *claims* and *data*. In order to identify arguments and types of arguments in a lab-report, we first coded each sentence before we inspected possible argumentative relationships between sentences. In a preliminary stage of the analysis we became aware that most lab-reports contained narrative step-by-step descriptions of what happened during the experiment, observations and measurements, scientific facts or statements and more. Using the constant comparative method (Strauss & Corbin 1990) in a preliminary analysis, we identified six types of sentences which were used in the final analysis of all lab-reports:

Problem formulation: Question or problem descriptions that do not include a scientific hypothesis (but only identification of topic).

Narrative sentences: Explains methods used, step-by-step: *what* they did or practical thing that happened during the experiment (not scientific observations, these are coded as observational statements). A drawing of apparatus is counted as one sentence, as are lists of equipment.

Factual methodological statements: Makes a principle or general methodological claim

Factual scientific statements: Refer scientific theory or a claim from a established scientific theory, as far as the student have understood it (Thus, we did not judge the quality or correctness of students scientific statements.)

Hypothetical statements: Factual claim stated conditionally or as a hypothesis

Observational statements: Statements, figures or sentences that declare observations or measurements made during an experiment (empirical data observed by others were marked with an asterix \*). A list of observations is counted as one observational sentence. When observations are presented in tables or matrixes, each column or row with measurements of different parameters are counted as an observational sentence.

Diverse statements: Factual sentences not about factual aspects of nature, observations or methodology, but 'Diverse' claims.

When coding, we defined all principal sentences as the unit for the analysis. Thus, where two principal sentences where combined using "and", the two principal sentences were coded separately.

To identify methodological arguments, we asked, for each narrative sentence and factual methodological statement, "Why did they do that?". To identify scientific arguments, we asked, for each factual scientific, hypothetical and observational statement, "Why is this so?". Nearby sentences or sections were inspected to see if they provided answers. In the first stage of the analysis of the lab-reports, we discovered that students sometimes wrote conclusions that, to be meaningful, presupposed awareness of earlier sections in the lab-report. Thus, we realised that arguments could be implicit, as the justification for a conclusion where given in a earlier section in the lab-report. E.g.:

*Result: The Magnesium and the chlorine acid produced a gas we call hydrogen. And when we lights hydrogen it produces a bang.*

In this example, we interpreted the production of the "bang" as the claim in the argument, and the scientific facts about the Magnesium and the chlorine acid as the explanation or justification for the observed "bang". The causal link is not stated explicitly, but is nevertheless implicitly present in the text. During the analysis, especial attention was given to possible implicit arguments. We also looked for linguistically expression indication justification-type of relationships between two sentences, e.g.: because, as, thus, consequently, shows. For each argument found, we identified which sentences served as claim and data respectively, including type of argument according to the definitions above.

The total strategy for identifying arguments thus consisted of the following steps:

1. Identification and numbering of all sentences in each lab-report
2. Coding of each sentence using the six types of sentences defined above
3. Inspecting possible argumentative relationships between sentences, including implicit relationships, and coding identified arguments according to the types of arguments defined above.

## **Identification of genres**

For the analysis genres in the lab-reports, Martin's (1993) conceptions of scientific genres were used, including the idea that a text might involve different genres in different sections. We judged the genre in a text section by inspecting the implicit purpose of the text and types of sentences in the section. As stated earlier, we became aware during the first stage of the analysis that many lab-reports contained narrative sections, lists of observations and textbook-like explanations. Further analysis led to the identification of three different genres:

Methodological narrative: Sections which explains chronological account of what was done, step-by-step. Kind of minutes. Does not contain methodological reflections, reasoning or comments on validity, reliability or generalizability of the experiment. The implicit goal is to make the experiments possible to replicate by others, as the teachers have demanded. As reflections and explanations are missing, the aim is not prevent later criticism. Thus, if a methodological argument is included, the section will be codes not at methodological narrative, but as experimental report (see below).

Scientific explanations: Explanations of relevant scientific phenomena, but without including arguments, explicit or implicit, where observations are used as data. The implicit goal is to show the teacher that one has understood the relevant scientific theory. It mimics the scientific genre *explanation* identified by Martin (1993). A section coded as scientific explanation will contain an explanatory argument.

Experimental report: Sections that somehow fits into the IMRaD structure and the process of presenting evidence and arguments for a scientific hypothesis or theory. The implicit goal is to present and defend the scientific hypothesis or theory, and thus to convince the reader that the presented hypothesis deserves to be given further attention. In a section on method, it was coded as experimental report if it included a methodological argument. A section on results does not need any arguments for this code to be used, but only presentation of observations. The section on discussion needs to include an empirical argument for an hypothesis for this code to be used. A theoretical argument might be present in introduction or discussion.

Based on these definitions, each section in the lab-reports were analysed and coded. When appropriate, the unit of analysis was the sections as defined by the authors' of the lab-report through their use of sub-headings or other means of layout. When a section mixed two genres, subsections were identified and coded. It was not taken for granted that the three genres defines was sufficient to categorise all text in all lab-reports. Martin's (1993) two additional genres, *exposition* and *bibliography*, could be present, as could other non-scientific genres. However, in the seventeen lab-reports analysed so far the three genres methodological narrative, scientific explanation and experimental reports turned out to be sufficient.

Following the section by section analysis, each lab-report was inspected as a whole. We judged to what extent the lab-report mimicked the IMRaD genre by judging the interplay between problem stated in the introduction, presence of arguments in sections on methodology, results presented and arguments in the discussions. In specific, we inspected how observations presented where referred to in other sections. Only two lab-reports included (implicit) methodological arguments. The definition of the genre experimental report as a defining characteristic for a lab-report as a whole was therefore adjusted and did not include the presence of methodological arguments.

The combined focus on genres and argumentation we accomplished by introducing the three operational definitions of scientific genres. In the seventeen lab-reports we found no sections where the genre identified was inconsistent with a type of argument present in the section.

To facilitate the search for patterns, all findings were entered into a matrix (in a MS-Excel spreadsheet) with one row for each lab-report and columns as shown in table 2 below.

## Results

### ***The teachers' requirements for lab-reports***

Both teachers, we might call them Anne and Brit, gave their pupils written information stating what sections to be included. Their requirements involved both similarities and differences. Ann asked her students to include *Heading; Aim/purpose/hypothesis; Equipment; Drawing; Procedure; Results and Conclusion*, while Brit required *Heading, Claim/hypothesis, Equipment, Drawing, Report, Results/explanations and Conclusion*. Ann's list of sections is rather similar to the IMRaD structure if we identify *Equipment, Drawing and Procedure* as method and *conclusion* as discussion. Brit's list has a similar likeness to IMRaD, but the heading *Results/explanations* does not differ clearly between results and discussion of results, and also the difference between *Results/explanations* and *Conclusion* becomes more unclear.

Ann also gave her students a list of assessment criteria. The second highest quality level read

*All sections in correct order. Uses right phrasings and concepts and shows that there are connections between aim and conclusion. Manage to show that the theory/purpose of the experiment is understood.*

Brit gave her students a sheet of paper with all sections written and with space to fill in content for each section heading.

During the interview, both the teachers explained that students often confused the content of the sections *Aim, Result and Conclusion*. In addition, they told that many students expressed frustration as to what to write in a *Conclusion*. Both teachers emphasised that they told their pupils that ideally it should give meaning if you only read the two sections *Aim/Purpose/Hypothesis* and *Conclusion*.

Ann and Brit stated that the pupils do not engage fully in the experiment if they are told they do not have to make reports, and that many pupils did not quite seem to understand how to learn science from practical work and report writing. They both explained to their students that lab-reports should be written so that others could repeat the experiment by using the information in the report. Moreover, the purpose was to learn scientific theory but also learn how to write reports.

Replicability and learning scientific theory are the indications given as to what is the goal or social purpose of the communication in the text (in addition to learning to write them), and thus indicates what genres to be used in the writing. The teachers used no kind of following-up activities. The report is handed to the teacher, commented, and assessed by the teacher. In sum, the teachers main requirements where

- All sections included and in correct order.
- Uses right phrasings and concepts which belong to science.
- Manage to connect relevant theory to the conclusion
- Text should give meaning if you read the aim and the conclusion only.
- Replicable for other just by using the information in the report.

### ***Types of arguments present***

The analysis of the seventeen lab-reports resulted in the identification of 250 sentences. The frequencies of the different types of sentences are given in table 2. Although we present figures, the distributions are not generalizable. However, they indicate the number of

instances the qualitative discussions are based on. In addition, some figures represent qualitative findings of presence or absence of categories.

**Table 2:** *The frequency distribution in the seventeen lab-reports of the different types of sentences.*

<b>Types of single sentences</b>	<b>Frequency</b>	<b>On the average</b>
Problem formulation	11	
Narrative sentences	111	6,5
Factual methodological statements	1	
Factual scientific statements	39	2,3
Hypothetical statements	10	
Observational statements	88	5,2
Diverse statements	0	
In total	250	14,7

Eleven lab-reports contained a problem formulation. The remaining six had a hypothetical statement in the introduction. All lab-reports included narrative sentences about method used, and observational and factual scientific statements. Observational sentences we found mainly in sections on results. These were often repeated in the conclusion and in four reports also in the section on method. Factual scientific statements we found in all sections, although mainly in the sections on results and conclusion. As the table shows, factual methodological statements were very rare.

Based on the identification of types of sentences and definitions of types of arguments, 29 arguments were identified. The frequency distribution of different types of arguments is given in table 3.

**Table 3** *The frequency distribution in the seventeen lab-reports of the different types of arguments. Numbers in parentheses indicates how many arguments we coded as implicit arguments.*

<b>Types of arguments</b>	<b>Frequency</b>	<b>On the average</b>
Empirical hypothetical argument	12 (11)	0,7
Empirical theoretical argument	0	
Explanatory arguments	15 (7)	0,9
Theoretical argument	0	
Methodological arguments	2 (2)	0,1
In total	29 (20)	1,7

All but two lab-reports contained one or more arguments. The two lab-reports with none arguments nevertheless contained observations, but these were not linked to any hypothesis or established scientific theory. The table shows that explanatory arguments are frequently present in the lab-reports. Six of the reports containing arguments did only include explanatory arguments. Consequently, nine out of seventeen arguments contained empirical hypothetically arguments. No empirical theoretical or theoretical arguments were identified. The lack of theoretical arguments shows that students never tried to justify a hypothesis by referring to consistency with established scientific theory. The presences of methodological arguments were rare.

## **Explanatory arguments**

A striking finding is the frequent presence of explanatory arguments in the lab-reports. The following example shows how the observed momentarily reaction between chlorine and magnesium is justified by explaining that “the two substances mixes, and turns into new molecules”.

*Results: Chlorine acid and magnesium had a momentarily reaction, and started to produce gas. What is happening is that the two substances mixes, and turns into new molecules.*

Importantly, it is not the observation that justifies the theory. The theory is presented as a justification for the observation: Chlorine acid and magnesium had a momentarily reaction (claim) because the two substances mix, and turns into new molecules (justification).

Even if these arguments are presented in lab-reports, they do not involve any hypotheses. What they compare are observations and established scientific theory: a deduced consequence of the theory is consistent with observations made. Within the seventeen lab-reports, explanatory arguments were found in lab-reports that did not use a hypothesis as a starting point for the experiment. Explanatory arguments were found in sections on results (4) and conclusions (11).

## **Implicit arguments**

As table 3 indicates, 20 out of 29 arguments identified were coded as implicit arguments. In *implicit empirical hypothetical arguments*, observations typically are presented in one section (*Results*), and a hypothesis explaining the observations in another (*Conclusion*):

*Results: Results from experiment A: We measured that the swing time increased a little when we increased the angle of deflection we used, from 9 seconds with 5 cm to 11 seconds with 15 cm. [... (results from experiment B and C)] Conclusion: It turned out that I was partly correct. The swing time increased when the angle of deflection was increased.*

Although it is not explicitly stated, the reader (the teacher) is obviously meant to understand that it is the observations stated in results that justifies and makes possible the conclusion. With one exception, we found *implicit empirical hypothetical arguments* in lab-reports where the student had formulated a hypothesis (in the introduction). Moreover, no lab-reports contained an explicit empirical hypothetical argument.

In *implicit explanatory arguments*, observations frequently were presented in *Results*, and a theory that explained the observations were presented in the *Conclusion*.

*Results: When we mixed the two reagents, it became white, and looked like a bit bluish milk. Conclusion: It was Barium sulphate that gave the white colour.*

In this argument, the student first claims an observation, “it became white”, and later the presence of “Barium sulphate”. The two statements are obviously related, but the relationship is not stated explicitly. However, the student indicates that the white colour was due to a produced substance called Barium sulphate. Thus the scientific claim about the white colour of Barium sulphate justifies, i.e. explains, the claimed observation.

## **Explicit arguments**

All but one of the nine explicit arguments are explanatory arguments. E.g.:

*Aim: Find out how the thickness of the oil varies with the temperature [[by observing the movement of balls placed in oil in a test tube]  
[...]*

*Conclusion: I found out that when it was freezing temperature it was slow, because the particles are lying very dense. When it held fridge temperature it was faster because it was some space between the particles.*

Here the conclusion includes two related arguments. In each argument, an observation is repeated, and a theoretical explanation is introduced using the word “because”. Obviously, we might discuss the quality and exactness of this explanation. However, using the word “because”, the student *does* make a logical connection between theoretical and observational statements. Explicit arguments we only found in lab-reports that, according to the wording in the introduction of these reports, did not test a hypothesis.

### **Types of genres present**

Through the preliminary inductive analysis of the lab-reports three different genres were identified. Using these categories in the further analysis, sections with different genres were identified in the seventeen lab-reports. The frequency for each genre is given in table 4 together with the frequency distribution for the two overall genres identified.

**Table 3** *The frequency distribution in the seventeen lab-reports of the different types of arguments. Numbers in parentheses indicates how many arguments we coded as implicit arguments.*

<b>Sections with different genres</b>	<b>Frequency</b>	<b>On the average</b>
Methodological narrative	19	1,1
Scientific explanations	12	
Experimental report	22	1,3
<b>Overall genre</b>		
Mixed genre	9	
Experimental report	8	

All the seventeen lab-reports contained a methodological narrative. Nine lab-reports included one or two sections identified as scientific explanations (and thus also included explanatory arguments). Thirteen lab-reports included on or more sections which was judged to be consistent with the experimental report (IMRaD genre).

In three lab-reports students had included scientific explanations under results. In these three reports the students repeated the scientific explanations in the conclusion. This indicates that these students were uncertain of the difference between results and conclusion.

Experimental report: Only one lab-report contained a methodological argument, and this was made in the conclusion. Thus no sections on methodology fulfilled the demands for an experimental report. However, if we redefine the experimental report, and not require a section on method to contain a methodological argument to be identified as a experimental report kind of genre. Using this adjusted definition, we identified eight lab-reports that contained a methodological narrative, a section with observations, and a discussion of observations. All but one of these lab-reports also contained a hypothesis or tentative claim in the introduction.

Mixed genre: The nine lab-reports with scientific explanations did not contain arguments where the students used observations as evidence. These lab-reports were a mixture of methodological narratives and scientific explanations. Thus, the observations served a quite

different role in these lab-reports than in traditional experimental reports. During the preliminary analysis, we wrote the following note on one of these reports

*Lab-report 3E1*

*Aim:* 1 Quest: To find out what happens with the water in the test tube when it gets heated?

*Conclusion:* The conclusion is based on an understanding of scientific theory about the particle nature of matter, and not on observations from the experiments verifying this theory.

*Observations:* In Results section: two observations/events (“It become much movement in the water and it squirts out through the pipe”). In conclusion: the two observations are reformulated and repeated.

*Purpose of report:* In both Results and Conclusion, the student chooses to write a kind of a textbook explanation, and not claims backed by observations as in scientific reports. The student makes explanations, using theory and resulting events, and thus linking events and theory as the teacher demands. The explanations include both a claim and events, and thus they are arguments. However, the focus is on the explanatory theory, and the data involved are stated as events in general, not as referring to the observations made by the student in the experiments. Thus, a possible conclusion is that the student believes the purpose is to show the teacher that she is capable of re-producing the correct explanations. This implies confusing the genre of scientific report with the genre of scientific explanation. The student fulfils the teachers’ requirements, but is nevertheless not separating observations and explanations, or making arguments clearly based on own observations.

The implicit aim in the lab-reports with mixture of genres is, in our understanding, to show the reader, the teacher, that one has understood the relevant theory through ability to explain this theory using observations as illustrations.

### ***Genres and the teachers’ requirements***

Experimental report: All but one of the experimental reports used the sheet of paper with pre-defined headings used by Brit, one of the teachers. In addition, these lab-reports contained a hypothesis in the introduction. There might therefore be a connection between Brit’s focus on students’ formulation of hypothesis and the students’ interpretation of the aim or social purpose to be to persuade the reader, the teacher, of the correctness of a hypothesis or a conclusion.

Mixed genre: The mixed genre used by five out of six of Anne’s students, is consistent with the requirements she communicated. Anne wanted her students to use scientific concepts and “to show that the theory/purpose of the experiment is understood”, but also to present “Aim/purpose/hypothesis; Equipment; Drawing; Procedure; Results” and to emphasis replicability. Thus, she asked her students to explain the science involved for the reader, and to explain for the reader how a experiment was made. And this was what her students did.

### **Discussion**

In this study, we found observations to be used in two different ways: Observations were used as *evidence* in lab-reports where a hypothesis was evaluated, and as *claims* to be explained by theory in lab-reports focusing on presenting methods and correct scientific explanations.

These two ways of using own observations corresponded to two types of arguments used in the lab-reports: empirical hypothetical arguments and explanatory arguments. Some arguments contained explicit clues about relationships between claim and data, while others did not. These arguments implicitly expressed relationships between observations and theories or hypothesis. In some implicit arguments even the observations were implicitly assumed. The two types of arguments corresponded to two of the three different genres used to categorise different sections in the lab-reports: Experimental report and scientific explanations

(in addition to methodological narrative). Nine lab-reports used the experimental report genre throughout, while nine lab-reports consisted of a mixture of methodological narratives and scientific explanations.

The two teachers' requirements for lab-reports had many similarities. However, the students making experimental reports had a teacher emphasising the formulation of hypothesis. The students writing a mixed genre, including scientific explanations, had a teacher who emphasised students' scientific understanding and use of scientific concepts.

This study only included only seventeen lab-reports. Through a preliminary inductive analysis we identified hypothesis and different types of arguments and genres. These qualitative findings, the categories, we believe are robust. However, the quantitative aspects, the frequency distributions and the correlations between requirements and content of the lab-reports we believe need a follow up study with a higher number of lab-reports to be confirmed or adjusted.

The two teachers involved in this study were conscious that they wanted their students to learn science from their writing of lab-reports. Our analysis showed that the students' lab-reports were written in two different ways, or genres: experimental reports and mixture of methodological narrative and scientific explanations. It is therefore relevant to ask whether writing in both genres stimulates learning in science.

The analysis revealed that all but two lab-reports in this study included scientific arguments. This indicates that the students did reflect on the relationship between own observations and theoretical prepositions. Thus, probably both genres are valuable to use in science teaching. However, we also found deficiencies in the lab-report, and to some extent these are related to the requirements given. Based on findings related to the two different types of lab-reports we will therefore discuss deficiencies and possible ways to improve students learning.

### ***Experimental reports and the nature of science***

The lab-reports identified as experimental reports shared many characteristics with the traditional IMRaD kind of report. However, many arguments were vague and only stated implicitly, and methodological arguments or reflections were rare. Moreover, comparison between hypothesis and established theory, which we called theoretical arguments, was not found.

To construct theoretical arguments to support or criticise a hypothesis might be too demanding for eight-graders, although evaluation of consistency with established theories are important in professional science (Kuhn, 1977). However, it is important that students understand the provisional nature of scientific knowledge, and the tentative and debatable character of science in the making. This epistemological understanding is important when students as future citizens meet different kinds of scientific texts with different levels of reliability. Thus, it is important that they learn not only about the structure and content of experimental reports, but also about its social purpose and the epistemic level of claims based on single studies.

When methodological reflections or comparison with established science are omitted / not included, students lab-reports express a naïve positivistic epistemology: To produce scientific knowledge, you state a hypothesis, follow a procedure for collection observations, compare observations with the hypothesis and states the conclusion. The questions about quality of methods and quality of observations, and thus also the tentativeness of conclusions, never arises. The lack of a section called discussion, but inclusion of the section conclusion, probably adds to this implicit message.

In order to increase the students learning of the nature of science in the making, we suggest the following to be included in the requirements for lab-reports:

- comments on the quality of methods and observations.
- explicit empirical hypothetical arguments.
- comments on the reliability of conclusions made.

However, it is important that the requirements are seen as meaningful by the students. To facilitate students learning about the characteristics of experimental reports and the nature of science in the making, the underlying ideas and social purposes need to be communicated explicitly. Thus, the science teacher needs awareness of the genre and the relevant aspects of the nature of science. As the experimental report aims to convince the reader about the relevance or reliability of a claim, the students need to be informed about a foreseen group of readers. If this is readers which have no previous knowledge about the experiment, it might feel more naturally for students to make their arguments explicit. If some readers, e.g. classmates, are to examine the reliability of conclusions, the inclusion of arguments and comments on quality might feel more naturally (Kolstø & Mestad, 2005).

In addition to leaning about the scientific genre experimental report and the nature of science in the making, we frequently want practical work to help students learn scientific theory. The teacher that required hypotheses to be made, picked natural phenomenon where an accepted but easy to detect relationship exist, however yet unknown to the students. Thus students where hoped to learn about this relationship from the experiment. When students have gained some competence in writing experimental reports, one might add a requirement asking students to compare their hypothesis with an established scientific theory in the introduction or discussion.

### ***From mixed genre to demonstration reports***

The lab-reports characterized as mixed genres deviated in important aspects from the traditional experimental report. First, hypotheses were not stated and compared with collected observations. Secondly, methodological arguments or reflections were uncommon (only one instance in eight lab-reports). Moreover, several students mixed the content of results and discussion.

However, these lab-reports did contain students' explanations of their scientific observations. We therefore believe the writing of these lab-reports facilitated students' learning, although they were not traditional experimental reports. On the contrary, they had several similarities with the scientific genre *explanations*.

By comparing them with explanation kind of scientific texts, we believe it is possible to increase its potential for facilitating learning. At present the mixed genre identified combines the idea of an experiment with the idea of using established science to explain observations. The teacher required her students to include information making the experiment replicable, but also scientific concepts and to show that the theory involved in the experiment is understood. Consequently, the teacher communicated two purposes for the texts, and thus two genres to be used, and the same mixed genre were found in the students' texts. Firstly, this indicates that the teachers' communication of purpose and requirement do have an impact on pupils writing. The consequences of adjusted requirements will therefore be interesting to study. Secondly, the mix of two scientific genres conveys an unclear or incorrect message to the students about the difference between science in the making and established science. The frequent combination of an open question in the introduction and established science in all arguments and conclusions adds to this message. Moreover, the mixed genre probably gives

students insufficient support to understand the characteristics and differences between experimental reports and scientific explanations.

We believe the above issues can be remedied by building upon the strengths of the mixed genre and make it even more similar to the scientific genre *explanation*. In many school science experiments the students learn the relevant scientific theory first, or are at least aware that an accepted scientific explanation exists. The experiments resulting in mixed genre reports was of this kind, which are often denoted as *verification experiments*: An experiment is put up to make possible certain observations, which are then explained using scientific theory. In fact, the idea of presenting an experiment, i.e. making a demonstration, and then explain the science involved, has a long history also in professional science (Sjøberg, 2000).

One possibility is therefore to separate clearly between two kinds of lab-reports, corresponding to two traditional scientific genres. With a clear focus on established science and its potential to explain natural phenomena, lab-reports based on verification experiments can convey insight into the nature of science and an important scientific genre. To make students' produce lab-reports in accordance with these ideas, the following might be included in the requirements:

- Use the phrase "demonstration report" in the heading
- Explain the procedures you used to make possible the observations
- Present the observations that are to be explained
- Present the scientific explanations for the observations made

These requirements does not deviate much from the one used by one of the teachers in this study. However, it does not contain the idea of conclusion or discussion (no uncertainties to be discussed), and it makes it clear that the students should not make hypotheses to be judged based on observational evidence. The teacher stated she told her students that ideally it should give meaning if you only read the two sections *aim/purpose/hypothesis* and *conclusion*. However, this is a feature of experimental reports, and not of explanations.

Nevertheless, it is important that these requirements are supported by explicit teaching of the difference from experimental reports, the social purpose of the text and of scientists' use of this kind of scientific texts. The use of both experimental reports and demonstration reports makes it possible to discuss similarities and differences with the students, and thus make it easier to see the difference between science in the making and established science. In the lab-reports with mixed genre several students confused results and discussion. By asking them instead to separate between observations and explanations this separation will hopefully be easier, and the half-way similarities with experimental reports will diminish.

Having said this, professional experimental reports often contain sections with explanations. However, these sections are subsections and are not an alternative to sections with empirical hypothetical arguments, but additional sections. The lab-reports with mixed genre found in this study did contain explanatory arguments but no hypotheses and no empirical hypothetical arguments.

## **Conclusion**

The two teachers involved in this study emphasised the potential for learning the lab-reports represents. Although most students included one or more arguments in their lab-reports, we also found an insufficient view of the differences between science in the making and established science implicitly expressed. The differences in requirements made by the two teachers correlated with the two types of arguments found in the lab-reports. Based on this, we suggest a more clear separation between two kinds of lab-reports: experimental report and

demonstration report. Importantly, these are rather similar to scientific text students' will encounter as future citizens, and they imply an adequate image of the nature of science.

In this study the teachers' requirements of lab-reports and communicated social purpose deviated in several aspects from the genres experiment and explanations identified by Martin (1993). After completion, the lab-reports are handed to the teacher, commented, and assessed by the teacher. Thus scientific critic of experimental report or evaluation of explanations by "peers" or other activities involving communal examination was included (Kolstø & Mestad 2003).

However, we believe the successful use of these two genres for lab-reports is dependent upon three conditions. First, students need to be taught the characteristics of the two genres explicitly, including its social purpose in the scientific community and the wider society. This includes instruction in the characteristics of empirical hypothetical arguments using own observations as evidence for a proposed hypothesis and explanations using observations as illustrations. Secondly, the students need to experience the social purpose of the two genres through the inclusion of anticipated readers and feedback in accordance with the social purposes of the two genres. Thirdly, to be able to guide students and to make inquiries into ways of adjusting their requirements, teachers need to have a sophisticated view of the nature of science and scientific genres.

Hodson (1991) have questioned the effectiveness of using practical work to learn science. This, in combination with the claimed potential of learning science through writing in scientific genres (Keys, 1999; Martin, 1998), indicates that our findings represent relevant hypothesis and suggestions for further inquiries. The explicit focus on the *experiment* and *explanations* as scientific genres is also important if we want pupils to understand science, and read science, and thus get access to the discursive power of scientific texts as future citizens (Keys, 1999).

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