A language sensitive pedagogy for science and technology:

Reading, talking and writing about practical work.

July 2015

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Contents

[1]This paper could not have been written without feedback on earlier versions, by colleagues, experts and students of Utrecht University of Applied sciences and elsewhere. We are grateful for their contributions.

1 Introduction

Yasmin, a student at secondary school, wrote a practical report. When she did so, she positioned herself in the role of a researcher who wrote a report for an imaginary customer. This customer suspected that too much salt had been added to the concrete mixture, which had resulted in decay of concrete. Yasmin figured out whether this suspicion was correct. Here is a fragment from her report:

> The sand that has been used for the concrete contained 0.3 grams of salt per 10 grams of sand. We have repeated our measurements twice, so we are reasonably sure about this conclusion.

Many of Yasmin's peers did not manage to write such a good conclusion and also in other sections of their reports we see that they find it challenging to produce the language of science. The interwoven nature of science and language can also be seen in the following formulations by students.

- Student to class mate: *The switch is closed, just like a door.*
- Student in research report: *We have measured the result of greasy food on the cholesterol level.*
- Student in exam paper: *There is a current on resistor A.*
- Person at home: *Watch out because there is electrical current on the wire.*
- *Salesman of mountaineering equipment: This rope can handle a force of 320 kg.*

In this article we describe how science and technology teachers can help their students, so they can become proficient in producing the language of science. We use the practical report as an example, but the approach can also be used for other types of texts. First of all we explain why teachers would want to ask for a report after doing a practical. We distinguish between two reasons for that: enculturation into science genres and writing as a way to process information.

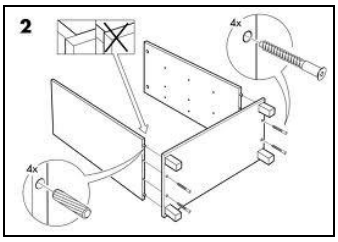
Reason 1: enculturation into science genres

Below you will see examples of genres that are related to practical work in science and technology. Can you guess where these texts come from and who the targeted readers could have been? And why would we enculturate our students into such genres?

1 Which food results in a lot of farting? Researchers from Harvard University found the answer.

Fake sugar

Substances such as xylitol in chewing gum cannot easily pass through the walls of the intestines. As a result ….



3

e. Check the free operation of valve number 2.

f. Replace the bearing after 100 hrs of operation

The above fragments are taken from respectively a popular scientific magazine for youths, an instruction from Ikea and a maintenance manual for operators. These are very different texts, that people encounter in daily life or in vocations and that can be understood by readers who have become familiar with the language involved. Some teachers even present real scientific research articles, in a simplified version, to familiarize their students with such text and give them an idea of how scientists communicate.

The Ikea fragment shows that, when we talk about 'language', we do not just mean the words and sentences, but also graphic representations. And symbols and equations are also part and parcel of science and technology language, according to our conception of language. We think of language as a system for meaning making in a social context (Halliday 2004). The first fragment above shows that the social context is indeed important if we look at the language. In a journal for scientists the word 'farting' would not be used. Yasmin, the student we started with, is also sensitive for the social context. She expresses herself formally, because her reader is a client.

A first distinction between genres can be recognized in the above fragments. Fragment 1 can be seen as 'explain', while the other two fragments can be characterized as 'instruct'. In addition, we distinguish between the genres 'describe', 'argue' and 'narrate' (Knapp and Watkins 2005). Yasmin for instance 'argues' why she is reasonably sure about her findings. In appendix 2 you will find these basic genres in one table. Which ones do you find important for your students and why?

Reason 2: Writing as a way to process information, to understand and remember.

The second reason of Yasmin's teacher, for letting his students writing a report, has to do with conceptual development. Writing is a way to process new information, to come to a better understanding and to find out what one does not yet understand (metacognition). Every teacher knows that conceptual understanding is promoted when students have to explain things to someone else. The students will structure their knowledge while writing, they decide what's really important and they build a coherent and logical form of reasoning while writing. Additionally, the students' writing enables the teacher to gain insight into the students' learning process, which in turn enables him to give precise feedback and to assess the students' work.

Other reasons

More generally, we know that writing in the content areas can contribute to the development of generic language skills. In this text we however like to demonstrate how talking, reading and writing can be a natural component of content teaching in science and technology. We do not focus on issues such as spelling. We use the practical report as an example and we think that you as a reader will also see ways to apply this pedagogy to other types of texts.

Writing is not under all circumstances an effective way to foster learning in science and technology. Sometimes students perceive writing as time consuming and burdensome. In that case they will probably learn very little from it (Ellis et al, 2006). Therefor it is important that the teacher selects writing tasks with care. We would also argue that it is important that teachers explicitly explain to students why writing a particular practical report helps to learn science or technology. Jack, a teacher in a vocational stream for students with special educational needs, frequently asks his students to reflect on the way they have executed a procedure: In terms of the genres in appendix 3: he asks them to write a procedural recount. He also discusses with his students where such tasks occur in vocations. The fragment below has been written after a soldering task.

> Finish the sentences below.
>
> First I have …….. put something together ……………………….

Jack then tells the student why a formulation like that is not yet good enough in a specific situation at the workplace, whereas the formulation would be perfectly fine in other situations. He offers the ways to use words such as 'soldering' and ways to indicate a sequence of actions. His students understand that such language is needed in vocations and they are willing to write such texts in lessons that are not primarily meant for language education.

Functions of writing a report are of course strongly related to learning objectives behind a practical activity. What would you for instance ask your students to write, if the learning objective would be: 'The student can build a series and parallel circuit with 2 light bulbs'? Perhaps you would ask students to take pictures of their circuits and present them neatly. But if you want them to be able to explain different phenomena when a series or parallel circuit is being used, a very different report would be asked for. The 4 types of practicals which we distinguish, with different learning objectives, are: the conceptual understanding practical, the skills practical, the research practical (Millar, 2012) and the design based practical.

The conceptual understanding practical

Students develop understanding of the natural world in scientific and technical terms, with the aid of experiences they encounter during the practical. Important function of the report: Developing understanding through a combination of experiencing and writing.

The skills practical

Students develop knowledge and skills to act skillfully in a lab or workshop, or to follow a procedure. Important function of the report: reflecting on the execution of the actions and henceforth gaining a greater understanding of one's own skills.

The research practical

Students develop knowledge, skills and a positive attitude towards scientific and technical inquiry. Important function of the report: Convince the reader that valid and reliable research has been carried out, whereby an answer has been found for a research question.

The design based practical

Students develop knowledge, skills and attitudes to design and make an artefact. Important functions of the report: Learn to take on the role of a designer, by writing as a designer; convince the reader that a transparent design method has been carried out and that the end product will meet users' needs.

Often one practical will combine different learning objectives. Van de Berg and Buning (1994) argue that one kind of learning objectives should be central, because it would be too demanding for students to learn such diverse things.

Intermezzo

Language is used in a particular setting with a particular purpose. How you say something, is related to that setting and on the people who are there. Look at the statement "*Would you care to talk a little softer, this is a 'silence train coach*'. The person who says this, makes a request, and that is very politely worded in a somewhat anonymous setting. Such a request may also sound like this: "*Hey, shut the hell up, I want to sleep*", between young people who sleep in the same room after a party. In the train compartment that language would have resulted in irritation.

This happens with written texts too. They have a function: they report, they argue, they instruct. And the way those functions are expressed, depends on the people who write the text and read, and on their mutual relationship. Where a scientific youth magazine would write "*thunderstorms occur when clouds clash*," meteorologist on a weather website would write "*A thunder storm is caused by rising and descending air currents in large rain clouds and by electrical fields between earth and atmosphere*."

Such choice of words and clauses can be expected when meteorologists want to express content and their sense of authority over this content. This aspect, that texts have certain functions within a context, and that incorporating words and formulations depend on the writer and intended reader, can also be recognized in lab reports. To make students master such texts, we as teachers have to understand how our language works. But before we look at the intricacies of our subject language in section 3, we will look at the kind of instructional sequencing that is likely to help our students.

2 Instruction and guidance for writing practical reports

Writing can be seen as difficult by students, because:

- They do not know how to start.
- They are unable to make the text coherent.
- They are unable to produce the abstract and formal written language of science and technology.

For teachers it is not always easy to help them. Understanding how subject specific language works and having heuristics at hand, can help to shape instruction and guidance in class.

Let us make the comparison with the way an experienced mason teaches his young colleagues the tricks of the trade. He will not limit himself to handing over a list of tips, tricks and rules. He will demonstrate parts of the bricklaying process and he will often point at examples of different qualities. He also has language available to talk about this, like 'gauged mortar' and 'struck joint'. If we want to support students to write in our subjects, we should also be explicit about the qualities of good products. And like the masons, we need language to talk about these qualities.

A staged approach to teaching to write

In this text we use a teaching learning cycle (TLC) as described in Rose and Martin (2012). We think of this teaching learning cycle as a set of tools that structures a pedagogical repertoire that experienced teachers may already possess.

Stage 1 deconstruction: Students and the teacher discuss how a texts are made up, they unravel exemplary texts and thereby gain insight into the most important quality characteristics. They also uncover how these characteristics are related to the (social) context in which the text is written. Students have ample opportunities to talk about the content and about the exemplary text(s).

Stage 2 Joint construction: the students write together (part of) a report under the guidance of the teacher. Again, there will be a lot of 'text talk' going on.

Stage 3 Independent construction: the students write independently, using the characteristics of a good report that they have discovered earlier.

The main objective of the TLC is learning to produce texts that are appropriate to the discipline, or genres. However, we want students to learn to use the scientific and technical genres creatively. The aim is not that students write template-like texts, using strict rules, but that they can take part in this important part of our culture (Christie & Derewianka 2008) at a level that is attainable for them.

Here you can see how teacher Rob uses the TLC.

Staging (shortened) of a lecture series by Rob. Topic: distillation

Introduction: Students search the internet for images, using the search term 'distillation'. They discuss in pairs what they see (context-rich). Rob explains why writing the report helps to come to an understanding of distillation.

Practical: Students perform a distillation of red wine. They record observations.

Rob follows the TLC.

1) Deconstruction: Rob shows a report of a student of last year, whereby he pays attention to strong and weak formulations of observations and conclusions. He shows his students a cross sectional view of the setup and tells why this particular kind of representation is useful in chemistry (it shows where entrances of glass tubes are blocked or open). Students copy part of the drawing and Rob pays attention to labels such "distillate".

2) Joint construction: Rob asks some students to formulate an observation. Turn taking is structured: he gives time to think and he gives feedback to make the wording stronger. After a few turns, the formulation "*the white drops coming from the glass tube taste dirt*y" has changed into "*the distillate is colorless and tastes like alcohol* ".

3) Independent construction: Students write their reports in pairs. In the conclusion, they provide a coherent explanation for the separation of water and alcohol at the level of particles. They use the theory from their books and they use words like "distillate" and "boiling point".

In this example we can see that the chemistry content is learned during the writing process and that students are enculturated into genres that are specific for chemistry or chemistry education. We will now discuss the TLC in more detail.

Stage 1: deconstruction

The basic idea behind this step is that students discover what choices are made to realize meaning in this content area and in this situation. They discover features of the language used. They may thereby also read the textbook under the guidance of the teacher: *"Do you see that on page 5? It says that there is* ***voltage across*** *the LED. This is how we say it in physics."* But the teacher may also demonstrate non-examples and explain why these lack a certain quality. Students can only learn the language of science and technology if they are challenged to produce this language both verbally and in writing. The teacher thereby gives feedback, so students have a chance to improve their language. Appendix 3 contains a complete example of written feedback by a teacher.

Proper start of your sentence, because you make clear that it is YOU who has conducted the investigation.

From our measurements we can conclude that the sand that has been used for the concrete contained 2 grams of salt per 10 grams of sand. We have repeated our measurements twice, so we are reasonably sure about this conclusion.

Usually we would use the word 'concentration' for this.

As we have stated, verbal interaction between students should also be stimulated by the teacher in order to develop writing proficiency. Mercer (2004) formulated a set of criteria for what he calls 'exploratory talk' in small groups For a set of criteria for the quality of group talk, we draw form.

- All information is shared.
- All students are encouraged to participate in the discussion
- Opinions and ideas are taken seriously and considered.
- Everyone is asked to give arguments for an opinion.
- Challenges and alternatives are made explicit and negotiated.
- The group is trying to reach consensus.

Students should understand that this is a form of discussion, a verbal genre, that belongs to science and technology. In scientific discussions at conferences for example, an open discussion about the methodology and the findings is to be expected. In addition to verbal interaction about a sample report, writing can also be practiced. If students speak the language of science and technology, this does not mean that they can write it too. Written language is generally more abstract, more precise and more formal than verbal language. An example of a written assignment during this first phase (on a design based report), is:

The exemplary report contains a 'program of requirements' for the design. Look closely at the wording of design requirement 1. Now formulate a design requirement for your own design, and use similar wording.

Reading plays an important role in the writing process. The following is an example that shows how the connection between reading and writing can be made at this stage.

Teacher: You're going to write a practical report that demonstrates your understanding of the concept of ‘force’ in physics. But how do we talk about force in physics? Now, **read** paragraph 3 silently [the students read]

In the second sentence we read: "A force of 600 Newton is exerted on the diving board, as a result of gravity acting on the person." Which verb is used in conjunction with the word "force"? [thinking time]

Teacher: Julian?

Julian: exerted

Teacher: Right. And do you see more sentences in which that combination is used between the words "force" and "to exert"? [thinking time]

Florence: Yes, in paragraph 1

Teacher: That's right, Florence. And can you give an example that shows that outside of physics people talk differently about forces? In sports for example? Give us a sentence that you would expect on a website about weightlifting, in which the word force is used. [thinking time]

Florence: A weightlifter can push a force up to 250 kg.

Teacher: Right, but in your report you can also write it say the way it is in the book: "a force is exerted." [teacher comments on the unit of force]

In this example reading is supported in a strong way. You'll probably find more information on reading strategies at your English department. And of course, science school books contain tasks that help students to process the information in the texts.

In summary we can say about this stage that sample texts are deconstructed with the intent to let students discover what language they can use in their report. Various methods may be used that activate students. We also saw that the writing skills of students may develop from verbal skills and from reading skills.

Stage 2: Joint construction

In this stage, the students and the teacher collaboratively write a section of a report, focusing on the characteristics of the genre. Here too, all kinds of methods that activate students can be applied. What matters, is that the students get support in writing and that the teacher models the writing process. It may even be helpful for the students if the teacher writes a few sentences on the board, while thinking aloud, deletes, looks up something in the book and tries again. This is a form of modeling that demonstrates the strategy 'kill your darlings’. Below you’ll find another example.

Teacher: You have done the distillation of red wine really well. Each group has written all observations in a Google Doc. Those texts appeared real time on my white board. So I have already looked at them, while you were still writing. Let's look at the Julia's first observation: "It stinks", I read here.

Whether this stunk or not, is an opinion of the observer. I, for instance, liked the smell. Julia, can you rephrase it in such a way that all classmates agree?

Julia: There's a sweet alcohol-like odor coming from the cooling tube.

Teacher: Good. That observation can now be rewritten in your own report.

Stage 3: independent construction

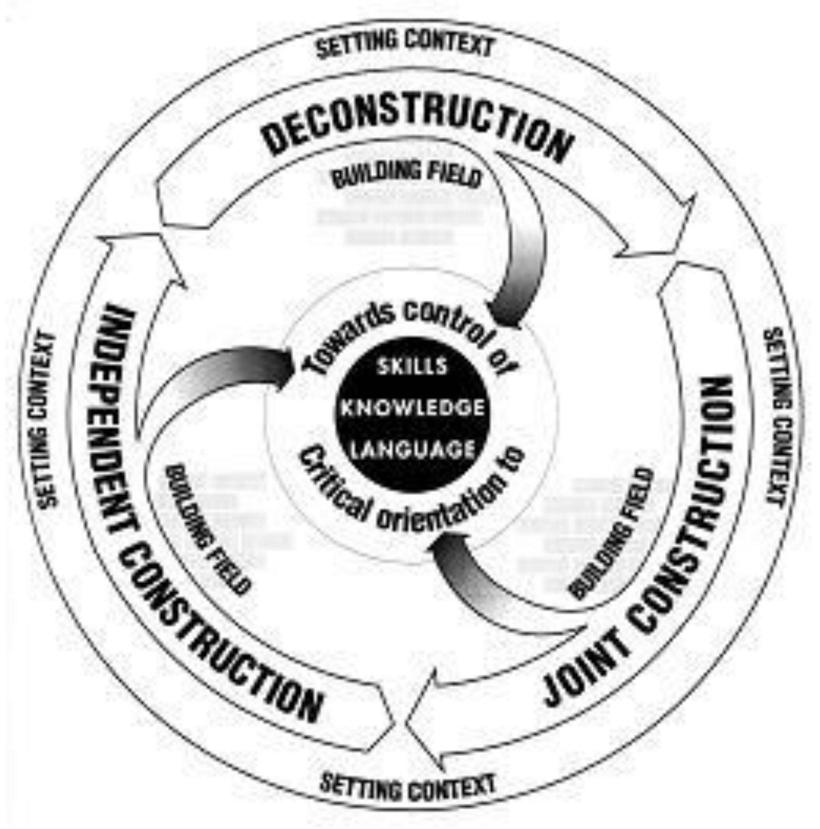
Now that the students have a good idea of the characteristics of the genre to write, they can write their own texts. That does not mean that support is absent. The teacher may give 'writing frame' for instance. The writing frame below is a scaffold for a report on a 'conceptual understanding practical' about a falling feather and a stone in a vacuum tube. It fits the Predict Observe Explain (POE) sequence that is common in science pedagogy.

My prediction was that the feather falling and the stone in the glass tube ... ..
What happened was that ......
Compared to my prediction ......
My explanation, using theory about, ... is ...

To make writing frames for the various types of lab reports, examples can be used that we give in the next section under 'structuring practical reports'. Assessment criteria and feedback on the final report, can be given in the form of a rubric. This example is meant for upper streams of science.

criterium	**Increasing quality →**		
Structuring of reasoning, from observations to conclusion.	The list of observations contains conclusions. 0-5 points		The observations and conclusions are separated. In the conclusion section, observations are related to theory. 6-10 points
The discussion with attention to level of uncertainty of answer on research question.	No arguments are given for reliability and validity of answer. 0-3 points	Arguments either about validity OR reliability. 4-6 points	Arguments about validity AND reliability. 7-10 points

The three stages that we have discussed are shown as a model below (Rothery 1994 in Rose and Martin, 2012)



From the inside out, we see the concentric circles:

Control and critical orientation: The pedagogy facilitates control over verbal and written language by everyone, even by students who have not acquired all kinds of (cultural) aspects of academic language at home at an early age. This control gives students opportunities at school, in everyday life and in future professional life. However, control over language is something else than to merely imitate examples. 'Critical orientation' in the heart of the model means that students can creatively use the language, be part of it, criticize it.

Building field (content): Developing an understanding of the content does not necessarily take place before the writing, as we have seen.

Three stages: Deconstruction, joint construction and independent construction as described above. The system that we use for taking apart the language of science and technology, will be described in the next section.

Setting context: The verbal and written genres are placed in a context. In the role of a researcher, who presents for unknown colleagues, students speak differently than when they speak for their own classmates in their role as a fellow student.

3 The language of practical reports

It is important for students that they discover what the qualities are of good reports. We successively discuss the organization of the text and the characteristics at word and sentence level. In this way we build a 'knowledge about science and technology language'.

A Text organization

For each of the main types of practicals we give an example of the organization of a report that fits the function of the practical. Because the emphasis is on organization, we have omitted a lot of text. Blue text is intended to illustrate what could come next.

Reports about research practicals

Title: Corrosion of iron under different conditions

Introduction
This research report is about corrosion of iron in dry and wet, hot and cold, dark and light conditions.
The study was carried out because we wanted to know ....
Research question: ....
Hypothesis: ....

Research method
We have carried out the investigation as follows: ....
A cross sectional drawing of the setup:

results
A measurement of the ... yielded ....
A table in which the measurements of … are shown ....
A graph in which the ... is plotted against ....
A calculation of the .....

discussion
Our results are partially consistent with the theory .... because .....
What we do not know for sure after this investigation ...... because ....

conclusions
From the observations, we conclude that our hypothesis ....
The answer to the research question is ....

Reports about conceptual understanding practicals

Title: The differences between series and parallel circuits

Purpose of practical
By means of this practical I wanted to develop a better understanding of the theory about electrical circuits

prediction
Before the experiment I had written the following prediction:
If, in an experiment .... , then ....

Observations and results
I saw ....
When we changed ...... , ... happened.
A table of the measurement ......
A calculation of ... .

Comparison of prediction and observations
My prediction was confirmed / not confirmed , because ... ..
I can explain this as follows, using the theory about ......
....

Reports about skills practicals

Title: Operating a microscope

The aim of the practical
I did this practical to practice with using a microscope.

Procudure
I have executed the procedure as follows:
1 Firstly I ......
2 Then I ....
3 A sketch of the situation at that moment ....
4 ....

Reflection
The practical has helped me in the following way to develop my skills.....
What I need to practice more, is ...... because ....

Report about a design based practical

Title: Designing a bookcase
name:

Introduction and design problem
A design for a bookcase was a needed for my sister ..., because……

Programma of requirements
The following requirements needed to be met:
1 The design must... because ... ..
2 ….

Design Process
First, the needs of the client were investigated, using ....
Subsequently, the program of requirements was drawn up and discussed with the client. That resulted in the following adjustments ......
After that, I worked on different solutions (concepts), which resulted in the following models: foam model / sketches of part. ... [Photos and drawings]

Solutions

Concept 1 (name and picture). This concept is characterized by ... ..
Strengths of the design are .... A disadvantage of the design can be ....
Concept 2 ....

Description of the prototype
We have chosen solution. ... because ...

Test results
To test whether the prototype met the requirements, the following experiments were carried out ... ..
From the experiments it has been found that ... ..
Recommendations for use and maintenance of the design are ….
......

Appendix: processing of materials and connections in the design……
....

The above examples of text organization are certainly not exhaustive or prescriptive. We do not use the term genre as an indication for one type of text with a fixed structure. We use it to indicate that the writer wants to achieve something particular with the text, in a social and cultural context.

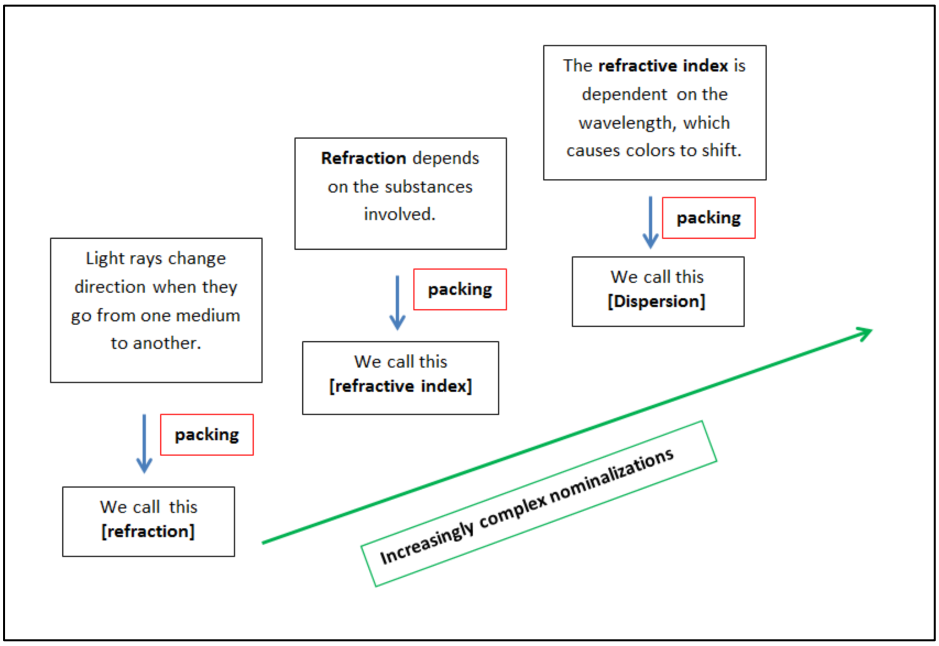
B Characteristics of words and phrases

The frame below shows two sentences from the conclusion of a research report, written by different students. The research question was: What factors play a role in the rusting of iron and how can you explain this?

> Jasper: Iron rusts fastest in a warm dark place, where it is a bit wet and salty.
>
> Florien: Factors that play a role in rusting, are a high temperature and the presence of salt and water. Rusting is a form of corrosion or oxidation. The reactants are iron, oxygen, and water. These substances are needed for corrosion.

We see from these examples that it is useful to illuminate language features at word and sentence level. Florien formulates a higher scientific level than Jasper, through the use of concepts. These concepts come with the theory (inheritance), but they can also be important in order to formulate the test method (the "*variables*" are kept constant).

The core concepts of science and technology are packed with more and more meaning in the course of a student's education. In the third year, the term 'oxidation' may mean 'reaction with oxygen', but in later years it may be associated with electron transfer. In this way increasingly specific meanings are packed into one word. And those meaning are often different from the meanings that the same word carries in everyday life. The 'packing of meaning' into concepts is sometimes referred to as 'nominalization'. The box below demonstrates how this works for the concept refraction.



You may not use the word ‘nominalization’ in class, but rather talk about science words or concepts. It is a word that we use as science educators among ourselves, who want to understand how our science language ‘works’.

An activity that help pupils on their way up in the graph, is a small group discussion on the basis of 'concept cartoons'. And to ensure that students learn to express the relationships between concepts or power words the teacher can ask students to make a ‘concept map’.

We can also see this as a development of 'Basic Interpersonal Communication Skills’ to ‘Cognitive Academic Language Proficiency’. In the previous section we have seen that teachers can provide support in a planned manner and that they can work from verbal language to written language (Gibbons, 2002). Subject teachers sometimes assume that subject language is only defined by its technical vocabulary. In the rest of this paragraph we will demonstrate that verbs and other components of subject language are also part of this ‘Cognitive Academic Language Proficiency’.

Verbs

Verbs are essential for a lab report. For example, they describe specific actions that need to be done during the practical (rinsing). If the student is expected to write, so that the procedure can be replicated by someone else, action verbs (in the imperative) can be used:

- **Expose** the plant to sunlight
- **Put** about 5 boiling chips in the flask
- **Shorten** the bar to 105 cm
- **Construct** the image

And when describing observations, verbs are used in a precise way, and often consistently in a particular tense: "We **saw** that the wine was bubbling '; "We **smelle**d a sweet smell '; "the droplets from the cooling tube **felt** warm.

But there are more complicated aspects of verbs. Concepts, objects and phenomena are related to each other through verbs: ‘Copper **is** a metal because it has the following features. ... It **belongs to** the semi-precious metals’. Other types of verbs have the function to attribute properties to substances, objects or phenomena: ‘Copper **has** a red color’. And sometimes it is important to express changes through verbs: 'Copper **became** red'

Verbs can also be closely connected to the science domain at hand. Such verbs can easily be identified in a schoolbook.

domain	**Examples**
ecosystems	to erode
separation	to extract, dissolve
light	to refract, polarize
energy	to contain, transfer, conserve, dissipate
digital electronics	to amplify, invert

Connective devices

Using proper text structure, concepts and verbs does not imply that a student uses science or technology language properly. The fragment below demonstrates this. Carl, the student who wrote it, had to explain why an electric motor would spin. He does use the right words, but his explanation lacks coherence and the science is not quite right.

> If the coil goes along the magnet, it will be attracted by the north pole and the coil becomes an electromagnet. When the coil has passed the magnet, it is no longer an electromagnet and then it will be attracted by the south pole.

To help a student like Carl, we need to address the science language, but not only at the level of concepts. The next section provides some ideas to do so.

Sometimes, the temporal order of things is important when describing phenomena or procedures. "**First** I saw that vapor came from the wine. **Then** there were small drops dripping down along the glass ". An alternative is to write a numbered list in which the sequence is shown. In (design and) technology texts this is particularly common.

The box below lists common 'signal words', cohesive devices that can help students make their texts 'stick together'. Most likely, they are familiar with these from English classes, but science need to help them use these words for science purposes. Can you tell, for each category, how such signal words can help in a practical report? For signal words that indicate time, we have already done so.

> **1. Time/order**
> firstly, in the end, in the second place, lastly, later, next, second, secondly, to begin with
> **2. Comparison/similar ideas**
> in comparison, in the same way, similarly
> **3. Contrast/opposite ideas**
> but, despite, however, in contrast, in spite of this, nevertheless, on the other hand, still, whereas
> **4. Cause and effect**
> as a result, because, for this reason, in consequence, in order to, since, so, so that, therefore
> **5. Examples**
> for example, for instance, such as, thus, as follows
>
> More examples can be found at the website where these examples originated from:
> http://www.uefap.com/writing/parag/par_sig.htm

We will give a few more examples of the use of signal words and other 'cohesive devices' to make text stick together. When phenomena are explained, and not only described, the observations are related to theoretical concepts.

> Bubbling of the wine at 80 ° C **is caused by** the alcohol, which boils at that temperature. **However**, the boiling point of water is 100 ° C, **so** the water remains largely behind."
>
> By means of the connective devices 'caused by', 'however' and 'so' an explanation unfolds.

Sometimes we expect from the students that their explanation uses theory at the level of particles. This should be made explicit to students: "*Explain that solids expand when heated, using a drawing of particles. Add a written explanation using the word "particles" to your drawing*.

In a conclusion of a research report, we often expect a form of inductive reasoning. Observations lead to a statement in terms of theory. Jolene for example writes: "*Magnesium powder has disappeared faster than magnesium ribbon.* ***This*** *is caused by a higher degree of partition,* ***which results in*** *larger surface area of contact with the acid. "* We call this a chain of reasoning. Such 'scientific reasoning' is increasingly valued in science education.

Magnesium powder **has disappeared faster** than magnesium ribbon.

This is caused by a **higher degree of partition**,

which results in larger surface area of contact.

If we want to teach students the language of science and technology explicitly, we can learn a lot from the language used by professional scientists and engineers. Below we give an example of a chain of scientific reasoning chain by an astronomer, who has written this text for the science section of a newspaper. Can you see how the astronomer has built a coherent text? Single words (connectives) are not the only means to achieve coherence in this text, by the way.

> If dwarf galaxies buzz around randomly, then we would expect that in half of the cases they circle around the main galaxy in the same direction. In the other half of the cases they would circle in the opposite direction. This is exactly what we found in our tests with the Millenium Simulation, one of the best representations of the universe. But when we looked at our sample of real galaxies, from the SDSS database…

With respect to sentence structure, it is also important to explicitly pay attention to 'standard word combinations' that are common for the domain, such as:

- **Seeds** are **dispersed**
- A **force** is **exerted**
- In the **reaction between** hydrogen and oxygen water **is formed**.
- The **voltage across** the lamp is 12 V.

C Tenor

In every text, relationships are expressed between the writer and the reader and between the writer and the content. In a design based report for a real client, for instance, the student wants to show that the design is a logical consequence of the program of requirements and that it has little to do with his personal taste. Therefore, he makes himself invisible by not using the first person ('I') . But if the teacher has asked his students to reflect on their soldering skills. Would you think the first person would be inappropriate in that case too?

> *"I found it difficult to solder the joints, which you can tell from the small lumps of soldering tin"*

In science education teachers sometimes think that professional researchers do not use the first person in research publications. But in actual fact they do use this, for example, if they interpret their results. Below is an example from the leading scientific journal 'Physics Letters'.

> *In conclusion, **we** have investigated the effect of the repulsive core on the linear, third-order nonlinear, and total ACs of an exciton in a QR.*

The relationship between the writer and the content

Some students express their affective involvement with the content in cases in which it is not appropriate for the genre. At the end of a design based report for an imaginary client, a student wrote: "*I found it very interesting to design the bookcase writing and I've learned a lot from it* ". A furniture designer would of course not write this. In most cases it is not appropriate for the cultural context of industrial design or carpentry, so it is only natural that you give the student feedback on this. But on the other hand, you may find it important as a teacher that a student can express feelings about the contents. In that case, you may choose to ask for a reflection, separate from the main text.

Students should learn that a certain moderation of tone, a degree of certainty, is common in science and technology genres. In a research report on reaction rate of chemical reactions, for example, the writer will want to express how confident he is about his findings from the experiment. And he will write in a somewhat detached way about the content. But in an exposition about environmental pollution, a genre that we don't discuss here, often a fiery and personal tone is chosen: "*PVC is very harmful to the ecosystem, especially when it is burned. It is therefore extremely important that we use alternative plastics*". By letting students explore such differences, without imposing strict rules that are experienced as oppressive and demoralizing, students can become sensitive to such aspects of science and technology language.

The language of technology

Up to this point, we have used examples from the languages of science and technology, whereby we assumed that there are similarities between those languages. However, there are differences, of course, that have to do with the different natures of the disciplines. In technology, forms of knowledge exist that cannot easily be expressed in language. Think about soldering. There is a lot of feeling, a developed intuition and embodied knowledge in it. But without denying the differences, we think that technology, like the natural sciences, can be seen as a knowledge domain (de Vries, 2012) that can be studied. In the pedagogy of technology, like in science, explication of the language is often useful for students. The examples from technology in this text, hopefully illustrate this usefulness.

4 The difficulty or level of language

The teaching learning cycle , as laid out in this text, can be useful for all levels of education. But there are enormous differences in the level of science and technology language that we can expect from students. These expectations should also result in an assessment that matches the level of education. The section of the rubric on page 10, for instance, is suitable for higher levels of secondary education. Examples of language at the right level can also be found in textbooks. Publishers often coach authors of those books, to ensure that the text is appropriate for the reading skills of the targeted students. Nevertheless, students need reading support. Teachers who skip the book, or who give such elaborate explanations that students do not feel the need to read the book, run the risk that their students are not exposed to ample examples of written language, at the level that may be expected from them. The development of their subject specific language proficiency may hamper as a result.

5 Wider implementation of a language sensitive pedagogy

The teaching learning cycle can also be used for other genres, such as the argument, an answer to an open question or a narrative. You can start with this explicit pedagogy in a simple way and extend your efforts later. When teaching to answer open questions, you identify language (including graphic) qualities of an exemplary answer (stage 1). You then request the class to construct an answer to a similar question. You give feedback on the input of the students (stage 2) and thereafter you let the students write independently, based on a third question of the same type (stage 3).

This approach will work best when it is part of interdisciplinary school wide language policy. In that case, students develop their sensitivity to genres faster, because they do the same kind of analysis repeatedly, across different school subjects. In order to do that, the teachers do not only use the teaching learning cycle, but they also develop a common 'knowledge about language' . The ‘practical report analysis inventory ' (Appendix 1) may serve as a starting point for such school wide developments.

6 Questions

1. Chapter 3 in this article describes aspects of science language that you may want to discuss with your students. Appendix 1 lists these aspects.
   a. Which aspects of science language do you want to address in your upcoming lesson in a specific class?
   b. Have another look at the reasons to let students write in science classes (paragraph 1). What are the most important reasons for you?
   c. What do your colleagues in the science department think about the problems that students have with understanding and producing the language of science? What do they think about the pedagogy that is described in this article?
2. Choose a skills practical that you do with a class every year.
   a. Fill in the 'practical report analysis inventory' in appendix 1.
   b. Construct a 'writing frame' to help your students write the report.
3. Appendix 2 lists common genres. Row 2 of the table shows examples of 'products'. A practical report is often made up of several of these products. Which ones do you expect to see in:
   a. A report after field work in biology
   b. A report of a design process in technology
   c. A research report
4. Have a look at a particularly well written practical report by one of your students.
   a. How has this student made use of 'signal words'?
   b. What other qualities do you see in this report?
5. In this article we zoomed in on practical reports, because they can be very rich in science and technology language. But the teaching learning cycle described in chapter 2 can also be used for other types of texts. For what texts, other than practical reports, do you think you could use (elements of) this teaching learning cycle?
6. What opportunities do you see to use this approach at your school, wider than science and technology subjects?
7. In chapter 3 we have looked at the language of science and technology in a rather analytical way. To some extent that may be nothing new for you. Chemistry teachers, for instance, commonly have a very analytical way of looking at the 'language of chemical equations'. They really value the difference between a number that is written in subscript or in superscript and they discuss this with their students at length. But in this article we have also looked at qualities of text, such as the structure of a text, signal words and conjugations, that we think are important in science and technology. How do you think about the opportunities that you have, to use such insights in science and technology language for the benefit of your students?

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Appendix 1 The practical report analysis inventory (PRAI)

This inventory is meant to stimulate science teachers to think about:

- The learning goals behind writing a specific practical report (category 1&2)
- Aspects of science language that need to be addressed (category 3).

Choices between learning goals and aspects of science language to be addressed, need to be clearly related. Consider the goal *'learn how to use a piece of scientific equipment or follow a standard practical procedure, and thereby use science language'*. This could be matched by choosing for item 3E, '*the use of scientific names for objects and materials'*.

In every category you are free to choose more than one focal point.

1 Goals behind the practical activity. By doing the practical activity, and talking about it, my students: ☐ develop their knowledge and understanding of the natural world, in language that belongs to science. ☐ learn how to use a piece of scientific equipment or follow a standard practical procedure, and thereby use science language. ☐ develop their understanding of the scientific approach to enquiry, in language that belongs to science. (Millar, 2009 p.7)
2 Goals behind writing the practical report. By means of writing the report, the goals that are ticked above, are further pursued. Additionally, writing the report: ☐ helps my students to remember the things that I want them to learn. ☐ helps my students to gain insight in their own learning process. ☐ helps me as a teacher to gain insight in students' learning. ☐ helps my students to learn to write a kind of science text that exists in the world outside school, such as a ………………………. *(e.g. a report of field work, a research report, a report of a maintenance activity in engineering, an instruction manual for operating equipment)*

3) Aspects of science language.

Choose aspects of science language to support your students, for a particular practical report. Your choice depends on what you have ticked above. Instead of just ticking, you may want to prioritize: 3= very important for this practical report, 2 =medium 1= a little important, 0 = unimportant at this moment in my teaching of science language.

Text organization, graphics, formulas, coherence	☐ **A** A text organization, expressed in sub headings, that fits the goals behind writing the text. *Subheadings are …….;……..;……* *Genres that can be used under the subheadings, are: ………. , …………..*
	☐ **B** A combination of text, graphic representations and formulas that is consistent with the goals behind writing the text, such as …… *(e.g. a graph of temperature against time; isometric projection; a drawing showing a section of a plant cell)*
	☐ **C** Coherence (or togetherness) within paragraphs, to achieve forms of scientific reasoning, argumentation, scientific explanations and so on. Specify: ………….. *(e.g. a coherent causal explanation for spinning of the rotor of an electric motor)*
	☐ **D** Use of words that help to make the text stick together (coherent), such as 'signaling words' *(because; therefore; also; firstly; etc)*
Aspects of words	☐ **E** The use of nominalizations (or concepts). Meaning that is packed into those words. Concepts may be useful to express the content of the topic or to refer to science methods and procedures. The use of scientific names for objects and materials. Specify: ……….. *(e.g. frequency; photosynthesis)*
	☐ **F** The difference between meanings of words in daily life and in science, and the difference in meanings between domains within science. Specify: ……. *(e.g. the word neutral in this topic has to do with acidity, not with charge)*
	☐ **G** The use of verbs that belong to the topic, or that refer to method and procedure, such as … *(e.g. nitrify; react; refract; measure; assemble)*
	☐ **H** The choice for the tense and other conjugations, such as….. *(e.g. I 'measured' the length, rather than 'measure' the length)*
	☐ **I** The use of standard word combinations that are important to the content of the topic, or that refer to science methods and procedures, such as …….. *(e.g. Force is exerted; voltage across)*
Language between persons	☐ **J** The extent to which the writer makes himself directly visible in the text, for instance by using or avoiding 'I', or 'we', in a way that fits the genre. Specify:……… *(e.g. Do use 'I' in your report, because you are reflecting on what you have done and what you have learned)*
	☐ **K** Expressing of personal emotions, evaluations and judgments that fit the genre, with appropriate strength. Specify: ………. *(e.g. the conclusion of your report is factual. Leave your emotions out in this case)*
	☐ **L** Expressing one's own idea only, or demonstrating awareness of other ideas, including those that that are accepted in science. Specify:………. *(e.g. demonstrate to what extent your findings correspond with the science theory in your textbook)*

1. Chose one of the aspects that you have ticked.
2. What would a student write if he does not yet master that aspect?
3. What would a student write if he does master that aspect?
4. Repeat this for two other aspects.

Appendix 2, categorization of genres (Knapp & Watkins, 2005)

Genres

	DESCRIBE	EXPLAIN	INSTRUCT	ARGUE	NARRATE
What they ' do' between people	**scientifically or technologically**	**by formulating causes and effects**	**by telling someone to do things in a certain order**	**by elaboration about a proposition to convince readers**	**by bringing order to things that have already taken place**
in products such as	- Technical description - Scientific research report - Definition - Problem or question	- Explanation how or why - Illustration - Conclusion in a research report	- Procedure - Instruction - Manual	- Essay - Discussion - Evaluation - Discussion in a research report	- Personal story - List of observations
Text organization	1. Classification 2. Description for each class/type	1. Phenomenon 2. Influence of different factors, causes	1. ObjectiveDoel 2. Materials 3. Steps to take	1. Proposition 2. Arguments, counter arguments, rebuttal 3. Solution	1. Oriëntation 2. Description of events in temporal order

Texts are often composed of several of the above genres. This also applies to practical reports. A report of a conceptual understanding practical may consist of a 'problem', a 'procedure', a list of observations' and a 'proposition', whereby each component is constructed as outlined above.

Appendix 3: Example of a practical report

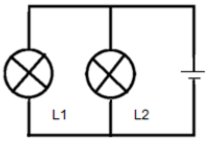
A report with written comments, such as the one below, can be used by a teacher in stage 1 (deconstruction).

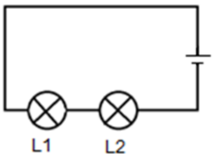
Practical report series on and parallel circuits
Jacob van Mil and Yasin Dogun
Class 3b

You understand the aim of the practical

Introduction

This practical is about two different kinds of circuits. A parallel circuit, and a series circuit. These circuits can be encountered in almost all electrical installations. We look at the differences between the two circuits when we remove one bulb. We have conducted the practical to understand the theory.





You use schematic circuit drawings the right way.

Materials

Power supply, 2 bulb holders, wiring

Procedure carried out

1 One person collected the materials.

2 We connected the power supply to the mains and adjusted the Voltage to 4V.

3 We built the circuit with the correct colors of the wires.

4.We checked the circuit before we switched the power supply on.

5. [...]

You use 'we'. As a result, the reader understands that this was your way of carrying out the practical.

You describe the **procedure** in de form of a list. This makes the stages very easy to follow.

Observations

Parallel circuit	**Series circuit**
When we took L1 out, L2 still burned.	When we took L1 out, L2 also went ou.

You use a table for the observations to make the text more structured.

conclusion

From our practical we learned that when a lamp is switched off in a parallel circuit, the other one remains on. In the series circuit if one lamp is switched off, the other also goes out. This is because the chain of the circuit is broken if a lamp goes out. In a parallel circuit, each lamp has its own circuit. If one fails, the other one is still connected to the power supply with both ends.

You use the concepts series and parallel correctly. You also use the verb that are suitable for his content: switch off, connect.

Reflection

We have done our best, but we worked too slow. The division of work was okay. We both participated in the making of the circuit and the writing of the report. We understand series and parallel circuits because now we have built it, and because we wrote the report. We now understand circuits in the home, which we think is cool.

The organization of your entire report is suitable for a practical that is meant to increase your understanding.

It is appropriate that you have used a personal voice, because you look back at your own actions and learning.