A new approach to improving the scientific writing skills of second year physics students

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I. Introduction

In the years I've worked as a bachelor student in physics at the VU, I've heard complaints from several students that the demands on the report of the bachelor project are very different from the demands on the practicum reports. However, when analyzing the demands the reviewers of both types of reports have, they appear not to be so different. Apart from that, I've heard several people in a group at the VU complain about the bad writing skills some students have at the end of their bachelor. Also, in my own experience there are huge differences in the writing skills of first year students.

This gives rise to the question whether there is indeed a gap between the demands reviewers from the groups and people from the practicum lay on a report.

Secondly, how can we improve the scientific writing skills of the bachelor students? To answer this question, it is necessary to lay out some boundary conditions: What is a good scientific report? And what are the required skills to write a good, scientific report?

After a quick review of the student reports I've noticed one major issue: all reports lack cohesion. It looks as if students try to fit their report into a framework instead of asking themselves the question: What do I want to tell? When they start writing their report they should have in mind what their *main point* is and start writing from there. They have to think of every word, sentence, paragraph and chapter as a part of the whole report, with which they want to communicate one main message. In their end product it should be clear of every word, sentence, paragraph and chapter what its purpose is. The report should have a clear line, building up from a clear and complete problem statement to a well founded conclusion.

Therefore, the main goal of my project is to improve the cohesion and efficiency of the student reports. In this I mainly focus on writing style and structure of the report and not so much on the scientific content. The latter is pretty well covered by the already present checklists by which assistants judge student reports and therefore falls outside the scope of this project.

In order to follow the student progress during the project I've created a checklist which is presented in chapter II. Apart from the practicum teacher J.B. Buning two people from a research group at the VU participate in the project. They are interviewed to see if they judge the quality of reports on the same grounds as the people at the practicum do. Also, they read the students third reports of the year and review them. This is done to create some extra pressure for the students to write a high quality report.

II. Research method

The focus of the research lies on the *structure* and *style* of the report, and not so much on the content. However, structure, style and content are of course connected in practice. The hypothesis is that a report *needs* a good structure in order to present good content. If the content is good, but the structure is bad the message doesn't come across to the reader. Therefore, a good structure is not *sufficient* but it is *essential* for a good report.

Tracking the progress: a checklist

Since I want to improve the writing style and cohesion of the student reports, it's important to track the quality of the structure of the reports. I've created a checklist (presented in chapter III) based on the *"Weitzlab guide to good paper writing"*[1], as published on the Harvard website, and on experience from both myself and students laboratory teacher J.B. Buning. The checklist was also presented to two experts from the scientific field to see if our ideas of the quality of students reports match those in the field (see chapter IV). All student reports are checked by me according to this checklist and the average scores on every point on the list will be presented in chapter VI.

Improving the quality of the reports: a writing guide

In order to improver the writing style and cohesion of student reports I've created a paper writing guide (presented in the appendix). This guide was handed out *after* the students wrote their first report. The first report of the year was used as a reference to see if the handout could improve the quality of the subsequent reports. The guide tries to prevent students from convulsively fitting their report in a framework, and instead tries to make them think about the *purpose* of their writing. The effects of the guide are measured with the checklists and feedback from the students on the usefulness of the guide.

The participants

The student group consists of (only) five second year physics students. These were all the students who did the second year practicum from beginning to ending during my research. Of course this is a very limited amount and so it's not possible to do thorough statistics on the checklist results. The results of the checklists are therefore merely an *indication* of the student progress. In addition to these results I've described some specific cases which illustrate the progress and problems of the students.

Finishing the research: the output

The output of the research will consist of a checklist for practicum assistants which can be used to judge the student reports as well as a handout which can be given to the students in order to improve their writing skills. The results are therefore twofold: partly it gives suggestions to improve the role of the assistant (teacher side), partly it consists of a method which students can use to improve their writing skills (student side).

III. A good scientific report: a checklist

As mentioned before, I've created a checklist which sole purpose is to test the structure and writing style of the student reports. It was partially based on the "*Weitzlab guide to good paper writing*"[1], and partially on experience from both myself and the practicum teacher J.B. Buning. The checklist consists of 13 demands a good report should fulfill. Every demand is judged on a 5 point scale, reaching from -2 (very bad) to +2 (very good). The 13 demands are:

1. Reading the introduction and conclusion *alone* gives a good idea of the experiment.
2. In the introduction it becomes clear what the research question is.
3. The conclusions match the introduction.
4. The report has *one* key message.
5. All theory described is relevant for the rest of the report.
6. All presented results are relevant for the conclusion.
7. All figures are relevant for the conclusion.
8. The results *support* the conclusion.
9. *All conclusions* are well founded.
10. *All premises* are well founded.
11. The transition between chapters is fluent and natural.
12. The transition between paragraphs is fluent and natural.
13. The writing style is efficient (no unnecessary sentences as "I'm now going to describe the results").

This list was also presented to the two people from the research groups and the practicum teacher drs. J.B. Buning and all agreed on the contents and had nothing to add.

Although the list mainly focuses on structure and writing style, one could argue that the foundation of conclusions and premises (points 9 and 10) judge scientific content instead of structure. This is indeed a point where structure and content are very much connected. It is a good example to show why a good underlying structure is *essential* to present the content in a clear way: foundation of conclusions and premises is a part of the content, but to found conclusions and premises the author must present relevant results and theory in the respective chapters. The connection between results, theory and conclusion is definitely a part of the structure. An author should think what results he presents and what theory he needs to found statements he gives in the conclusion paragraph. This comes down to asking the question *why* the author wants to write something, and thereby it is a matter of cohesion.

IV. Experts opinions

To further investigate whether the demands of the practicum teacher and assistants and of people from research groups match I've had an interview with the two people from the Biophysics group at the VU.

In the interview I asked what conditions a good scientific report should fulfill. From their answers, the following list was

- What was done?
- Why was it done?
- What were the results?
- What were possible errors?
- What suggestions can be given for future research?
- All conclusions and premises should be well founded.
- Everything has to be done in context, meaning that:
  - Interpretation of results must be done in the context of the theory
  - If necessary, different results should be used together to draw one conclusion (or stated inversely, every conclusion is preferably founded by more then one result).
  - The theory must be put in a physical context. It has to be clear what the formulas mean and why they are important for the experiment.
- Error margins should be given at all times.
- The analyses of results must be done in time, to prevent conclusions like: "We think we made a mistake when measuring this point."
- Writing style should be efficient and to the point.
- Formulation should be precise and exact.

An interesting remark was made which shows that the experts also note students sometimes try convulsively to fit their report in a given framework. One of the interviewed people mentioned that students should listen to their intuition when writing a report. For example, one student who measured the effect of fuel temperature on the performance of a fuel cell mentioned in his report: *"The exact value of the temperature is not important, for we only want to measure if the temperature has any effect on the performance."* The student probably didn't really believe that knowing the temperature was unimportant. Instead, the student just didn't measure the temperature and wanted to justify this quickly, even though it was against his intuition what he wrote was correct. In this case the student tries convulsively to 'justify everything', as he has learned. However, in doing so he undermines his own credibility by giving a clearly false justification. It would have been better to really ask himself *why* he didn't measure temperature. The answer would probably be: because he didn't have the time.

A second remark was made about the order of writing. One of the interviewed told that she advised her promovendi to start with making the figures and writing the figure captions. By doing this, she could quickly see if the promovendus had a good basis for his paper or not. From the figures then follows the conclusion and only after that the rest of the report is written.

V. In practice: helping the students with a writing guide

Looking at the list above, the experts judge reports on the same grounds as we at the practicum do. The remark that students should use their intuition when writing a report is interesting. Apparently, students know very well they have to justify everything they conclude. However, sometimes they make mistakes and because of the limited time they have for an experiment, they sometimes try to cover up their mistakes by knowingly making a 'false' justification. Because they think they have to.

From my experience in previous years, I conclude that students tend to put much effort into fitting their report into a given framework, instead of asking themselves the question *why* they write something. They are aware of the general outline of a report (introduction, theory, methodology, results, discussion and conclusion) and are usually able to use this outline. However, their reports often miss cohesion because they write every chapter as a separate text, not thinking about the purpose of the chapter for the whole report. To try to change this, I've developed a writing guide (in Dutch) which can be found in the appendix. In the next chapter, I'll give an English summary of the main points of the guide.

VI. A guide to good paper writing

In the guide I try to show students they have to continually ask themselves the *why* question when writing a report. This starts with the question: *why do I write my report?* (what do I want to achieve?). Usually, a scientific paper has the purpose to *convince* the audience of the conclusions the author has made. At the practicum, with the limited time available, it also sometimes happens that the purpose is more focused on giving information to a next group of students why certain measurements failed and how measurements can be improved. In general however I point out to the students that they should stand for their own results and show this in their text.

I point out that you have to analyze your results and draw a conclusion before you start writing, because otherwise it's impossible to know why you write your report (there are always students who start by writing their introduction or theory without even looking at their results).

Furthermore I show a figure (figure 1) in which the structure and cohesion of a report is outlined.

The students who participated in my research have all received a similar guide as presented here, after they wrote their first report.

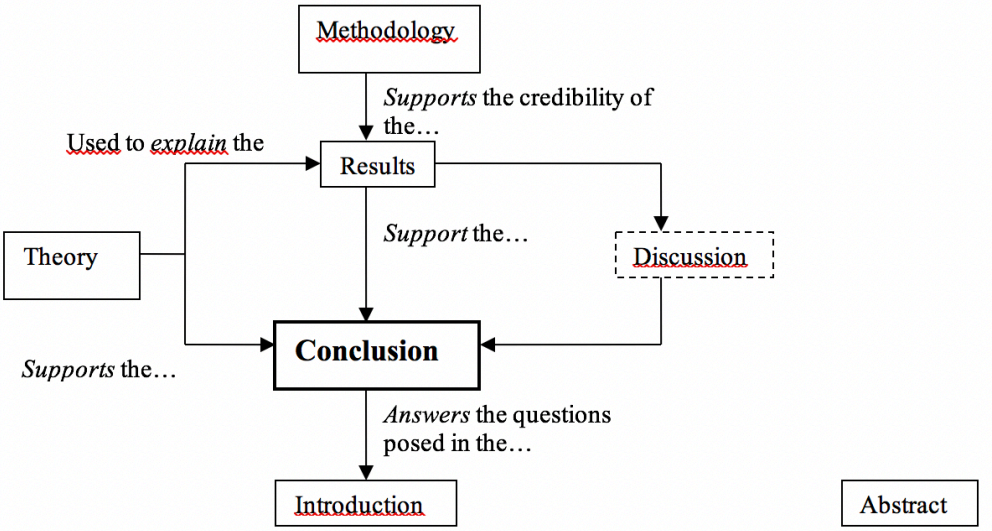


Figure 1 – The general structure of a report, as shown in the writing guide handout for the students.

VII. Results: before the paper writing guide

As explained in the methodology section, the first report of the students was used as a reference. Therefore, the students wrote this report without having seen my paper writing guide. When analyzing the first reports of the second year students with the checklist, the results are not so good. Figure 1 shows the average score of the first reports in the various categories. Because the number of participating students is only 4, no statistics should be performed on these results. The results are merely an *indication* of the student progress!

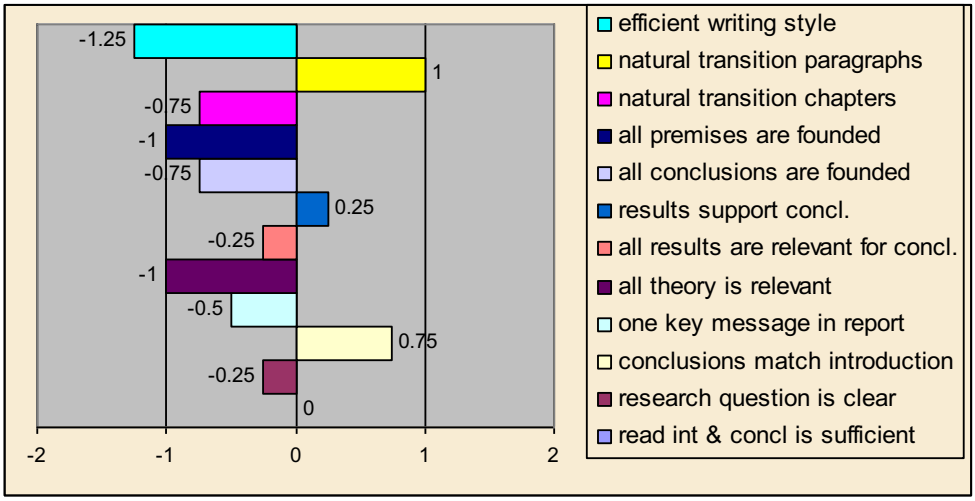


Figure 1 – The average score on the various categories for the first reports of the 2nd year students without the top student. The average over all categories is -0.31.

The graph shows that students have big problems with their writing style. They are not good at writing efficiently and the various chapters do not connect in a natural way. Students also do not succeed in founding their conclusions and premises. Furthermore they present a lot of 'unnecessary information', especially in their theory chapters. Students appear to have the tendency to show they understood the theory, instead of using the theory to support their conclusions and results. Sometimes they also present figures which don't contain any added value for the conclusion. An example is presented

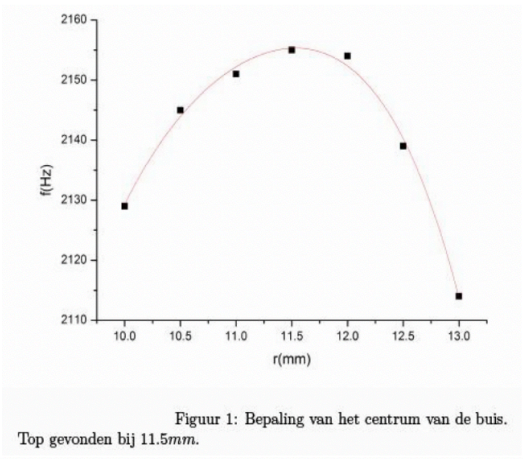


Figure 2 – An example of a student showing unnecessary results. Only the value of 11.5nm is relevant for the conclusion, the rest of the graph is not essential.

in figure 2. The student performed an LDA experiment on a tube with flowing water. For this it was necessary to determine the center of the tube. Instead of simply presenting the value r = 11.5nm in the methodology, he decided to give the graph as shown above, although it is certainly not a key result for his conclusion (at least in the way he uses it: only as an illustration of the number r=11.5nm).

Overall it looks as if students do not have a clear goal in mind when writing a report. They often *get lost in details* and *forget the main purpose* of their report. Sometimes they even fail to formulate a good research question. For example, one student wrote in his introduction:

"It is easy to notice that the frequency of the sound a glass produces drops when the glass contains more water. The question is what the underlying responsible mechanism is. It is stated in the article In Vino Veritas that the frequency drops because the extra mass of the water is vibrating with the glass. Based on this theory we've formulated some hypotheses and then we tested them."

Although we've some idea what the experiment is about, the formulation is definitely not exact nor very clear. Apart from the fact that this is confusing to the reader, there's also a risk that the students experiment won't be able to draw a good conclusion. After all, to formulate good conclusions it is very important a student clearly formulates *what* he or she wants to know.

The main problem

It looks as if students write their report starting from an *outline* (introduction, theory, methodology, results, discussion, and conclusion) instead of asking themselves the question: "What do I want to tell?" The result is a report which contains all necessary chapters, but doesn't have enough cohesion and contains a lot of unnecessary information. Students get lost in the details and thereby forget the main message of their report.

VIII. Results: after the paper writing guide

After the first reports the students received the paper writing guide. I've also explained to them the ideas behind the guide and how they should focus on *why* they write something, instead of focusing on the framework their report should fit in. The results were impressive. Students reported the guide was a good help to them and called it 'useful'.

The second report

This is supported by the results of the second report, which were already significantly better then the first (figure 3), with an average score of 0.52 (an increase of 0.83). The reports showed much more cohesion, with theory chapters containing only the necessary information. Conclusions and introduction matched better then before.

The research questions were usually present in the introduction, and the formulation was already much better. Sometimes there is still room for improvement, for example with the student writing:

"The shape of the IV-curve is given by the Tafel equation. The goal of the experiment is to determine the shape of this curve at varying hydrogen pressures for a PEMFC which receives oxygen from the air."

Although the question is complete, it could still be formulated more efficiently and clearer. For example:

"Because the activation energy decreases with the hydrogen pressure in the cell, we expect that the IV-characteristic is depended on the hydrogen pressure, particularly at low currents. The goal of the experiment is to check in a PEMFC whether the activation energy decreases with increasing hydrogen pressure."

This new formulation stresses that it is not so much the IV-curve, but the *activation energy* we're interested in. The IV-curve is merely a representation by which we can determine the activation energy.

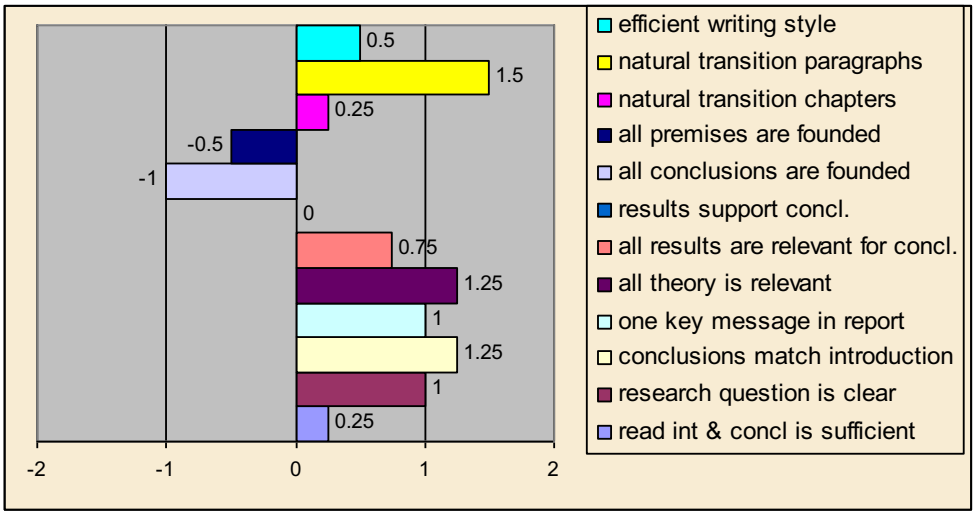


Figure 3 – The results of the second report. The overall average score is +0.52, an increase of 0.83 compared to the first report. Foundation of conclusions and premises is still a problem.

For most students it was still difficult to found conclusions and premises. For example, one student concluded:

"We didn't succeed in measuring Compton scattering. The big uncertainty in the results makes it impossible to determine whether we've measured Compton scattering or some other effect. The results suggest that doing more precise measurements might make it possible to measure Compton scattering."

Apart from the fact that this is a very disappointing conclusion, the student doesn't tell *why* the results suggest doing more precise measurements may make it possible to measure Compton scattering.

Must haves or key capabilities

Besides failing to found his conclusions, the student also fails on a key capability one may expect from second year students: quickly performing some first measurements can already show it is impossible to measure Compton scattering. A second year student shouldn't spend four afternoons measuring something only to discover that the measurements were not precise enough. Although this is not so much a point of structure and writing style, I still want to point this out. In my opinion, the judgment of reports and working style should incorporate some key capabilities a student has to posses. If the student fails on one of these points, he simply has to start over. In the present situation, there is no weighting between the different points on the checklists assistants use to judge a student. Ideally, the checklist starts with some "must haves". If one of these "must haves" is not present, the assistant can stop reading the report and give it back.

The third report

With the third report (figure 4) of the year the students had the opportunity to rewrite their report after receiving commentary from the assistant. In my project I've only analyzed the first report, because this gives a better image of what students are capable of.

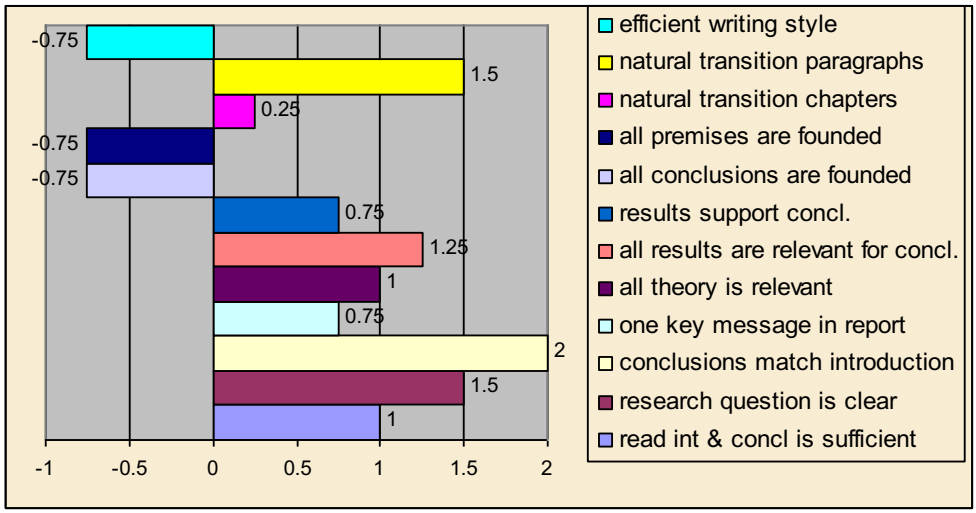


Figure 4 – The results of the third report. Overall average score: 0.65. Foundation of conclusions and premises remains the main difficulty for students.

The results look similar to the results of the second report, but with an overall improvement on most scores. The overall average score is 0.65, a small increase of 0.13 compared to the second report. Foundation of premises and conclusions remain a problem. One student tried to found his conclusions, but was a little too enthusiastic. He wrote:

"Another explanation would be that I used nickel foil instead of aluminum foil without knowing this. By secondary fluorescence the nickel would excite the iron atoms which would cause a great decrease in the nickel peak."

Probably the student didn't really think he made such a big mistake (an example of writing against his intuition, as one of the experts already mentioned in chapter III). He only tried to give an explanation because he learned that he must found his conclusions and give possible explanations for interesting effects. It is probably clear that using *this* explanation doesn't improve the liability of the conclusions…

The writing style of students is sometimes quite informal. Some students use sentences like:

"I can't exactly explain why the nickel series behaves like this. I have some presumptions, but first I'll discuss the iron series."

In my opinion, this is one of the key capabilities a second year student must have: a reasonably acceptable level of scientific writing style. If a student doesn't show this capability, there is a big problem. In extreme cases, it may even be wise to send the student to a writing course. However, often students should simply read their own report after they've written it. Most of them can detect these sentences and reformulate them.

The final report

The final report of the year is significantly better then the first (see figure 5). The overall average score was 0.75.

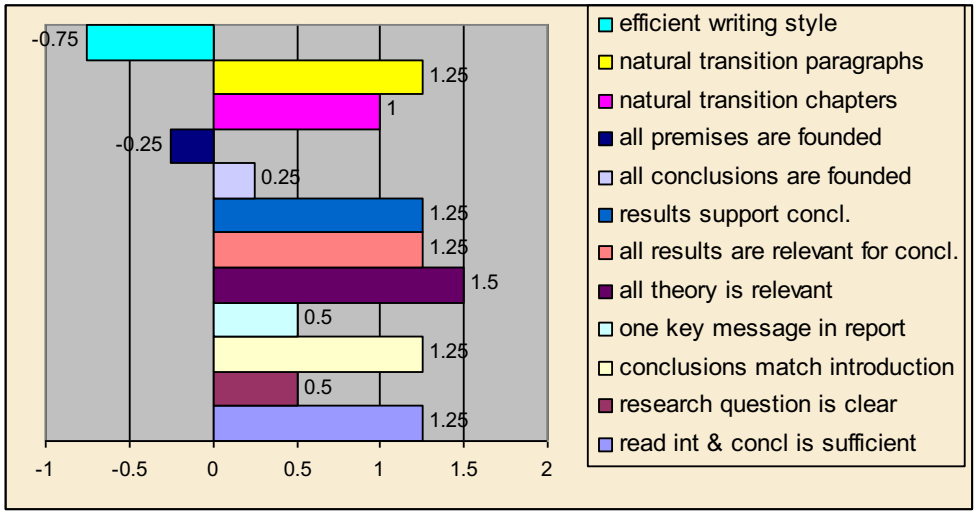


Figure 5 – Results of the fourth and final report. Overall average score: 0.75, an increase of 1.06 in comparison with the first report. Foundation of conclusions and premises has improved, but is still far from ideal.

Founding conclusions and premises: why structure is essential, but not sufficient

Students are slightly better at founding conclusions and premises, but the average score is still approximately 0 on this point. Sometimes this is caused by a misinterpretation of the results. For example, a student who measured light intensity under various angles through a prism obtained the results in figure 6 and concluded:

"The results do not support the Airy theory. The main reason is that the value of the intensity never goes to zero, but instead is 10nW minimum, while the theory predicts a periodic function which has a minimum of 0."

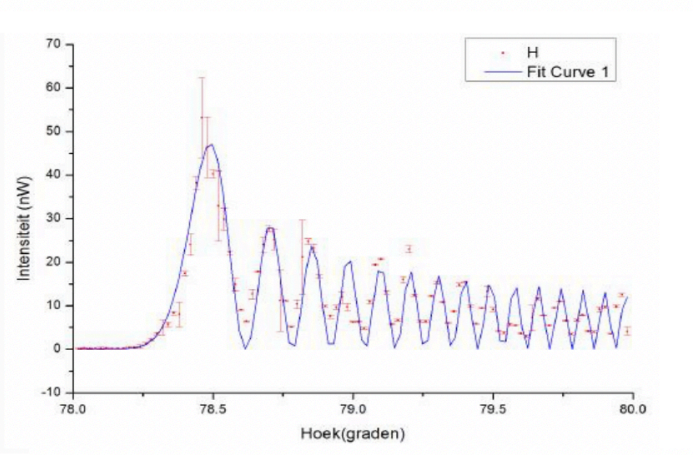


Figure 6 – The student concludes the results do not support the theory because the minimum intensity is not zero.

This conclusion is not very well founded by the result. In fact, it seems as if the blue fit matches the results pretty closely. Of course, there are some deviations and it looks as if the measurements are not precise enough. And of course, the local minima are not always zero. But this could be caused by some unknown error which caused an offset at higher angles. And by the way, don't we see a value of zero between 78 and 78.25 degrees?

If we look back at our earlier scheme depicting the structure of a report we can see why this structure is so important (see figure 7). In this case, the obtained results are used to test the Airy theory, which predicts that light which is refracted by a medium (for example a prism) will exit the medium at several angles, with a decaying intensity for larger θ. This decay in intensity is caused by a greater number of internal reflections for light rays exiting at larger angles. In fact, this is pretty much what we see in the results of figure 6. The student however concludes the opposite. In this case, the student is not able to extract the *essential* part of the theory. The essential part is *not* that the intensity goes to zero for some angles, but that there is an oscillating intensity, of which the maximum decreases for larger θ. Somehow the student doesn't see this, although it's quite obvious from figure 6. This shows the interconnections between theory, results and conclusion. Without the proper interpretation of the theory one cannot interpret results in such a way that good conclusions can be drawn. By misunderstanding the theory, the end result is that the students' conclusion is *not* supported by the results.

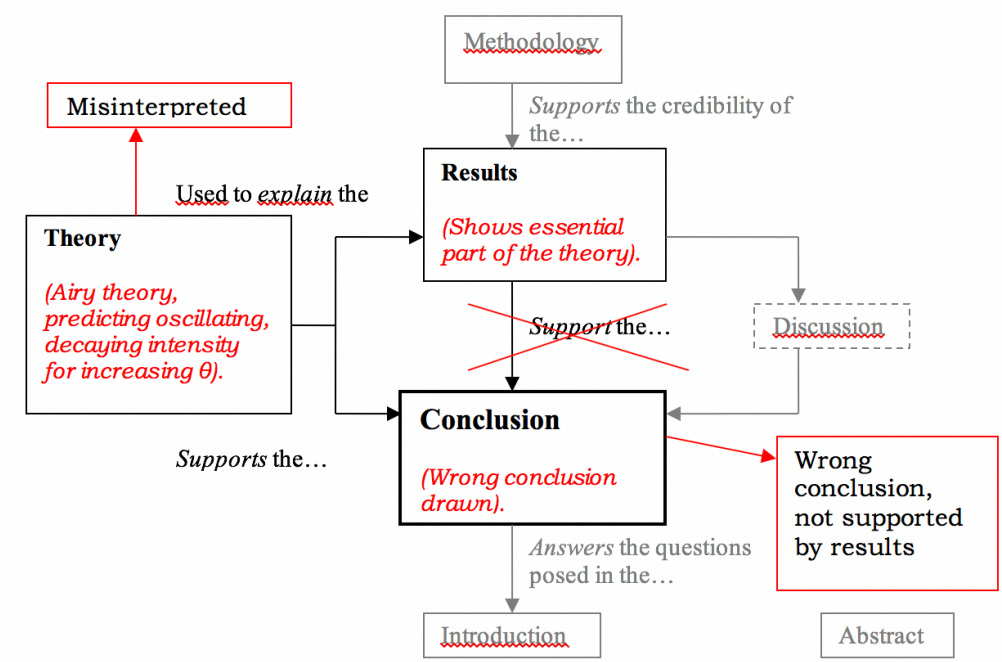


Figure 7 – A real life case, illustrating the importance of the structure of the report. By misinterpreting the theory, the student fails to interpret his results in the right way. Thereby he draws a wrong, unsupported conclusion.

In this case the good structure of the report was clearly not sufficient. Although all ingredients were present to draw a good, well founded conclusion the student still failed to do so. This is an example which shows that a good structure is *essential* but not *sufficient* for a good report.

So if the structure of the students' report is good, then what is lacking here? Apparently, (some) students have difficulties extracting the essential parts of theory and results and combining these into a good conclusion. Analyzing measurements is thereby quite difficult. This stresses the importance of analyzing the results together with the assistant, instead of home alone. By analyzing the results *at the practicum*, the learning or feedback cycle is much shorter. This can help students improve their analyzing techniques which I believe should be the next (content focused) step in improving the practicum education.

IX. Conclusions on the effects of the writing guide

1. Structure is essential, content is next

Overall the new approach to the student reports has paid off, therefore I suggest my checklist is merged with the checklists focusing on content already present at the practicum. The reports show much more cohesion then at the beginning of the project. The structure improved significantly, with most reports containing one clear message. The main difficulties still lie in founding conclusions and premises. These points are partially content related, as noticed earlier. A good structure is an essential basis to write

a good report and draw good conclusions, but it's not *sufficient*. The next step is to improve the analyzing techniques of students (a content related point). Students are in general able to present the right results to found their conclusions, but often still lack the ability to use the results to their full potential. Therefore I suggest the students analyze their results in the presence of the assistant, instead of at home. This gives the assistants the opportunity to give direct comments and provides a shorter learning (feedback) cycle for the student.

2. Showing key capabilities

When using the checklists such as the one created by myself, there is one important thing lacking: there is no weighting between the different points on the checklist. This is not conforming the natural way a teacher judges a student. After all, there are always some essential capabilities a student must have in his second year. If a student doesn't have one of these *key capabilities* his level is probably not high enough to move on to the next year.

One example is that students should not spend four afternoons measuring, only to conclude that the measurements were not precise enough. Although this is more of a content-related point, I still want to point it out since I think it is an essential part which misses in the current teaching practice at the practicum.

3. The writing guide is a great help, the practicum guide should be a reference

The final conclusion is that the writing guide has proven to be very useful for students. Therefore I suggest the students receive the writing guide as a handout. It is important that the focus lies on the 'why I write something' question. It should be prevented at all times that students convulsively try to fit their report into a framework. In the practicum handout which has been used at the practicum up till now there is a section explaining what the contents of the various parts of a report should be (i.e. What do you write in your introduction? What do you write in your methodology chapter?). This is good as a reference and students will definitely need it. However, it should be emphasized to students that it should be used as a *reference*, NOT as a writing guide. It does not teach how to write a report! Therefore it might be a good idea to give students my writing guide (or an adaptation of it) and explaining they should keep this guide next to their computer when writing a report. Then if they have more detailed questions about the contents of a report, they can refer to the practicum handout. Therefore I'd also suggest the writing guide does *not* become an integral part of the practicum handout, but is handed out separately to stress the difference between guide and reference.

Also it is important to point out here that *less is more*. We want the students to keep focused on the *main message* of their report. Therefore it is important we present them one *main message* which shows how to write this report. This main message should be:

"Think about *why* you write something."

Everything else we teach about structure is extra.

X. Conclusions about the checklist: possible improvements

The checklist given in chapter II proved very useful to judge the style and cohesion of the reports. Some small improvements can be made. The point "All presented figures are relevant for the conclusion" can be deleted. In practice, the point overlaps too much with "All presented results are relevant for the conclusion". "The transition between paragraphs is fluent and natural" can also be skipped. I've never seen a situation where this was not the case. Usually when a report was not fluent enough, this was caused by the use of complicated sentences, not so much by a bad transition between paragraphs. Therefore, a replacement for this point would be: "The writing style is fluent (no complicated sentences, easy to read)."
The last point of the list: "The writing style is efficient" needs an addition: "The writing style scientific (formal)." There is a difference between efficient writing and formal writing, which is why I think this point should be added. This results in the final checklist as shown below:

1. Reading the introduction and conclusion *alone* gives a good idea of the experiment.
2. In the introduction it becomes clear what the research question is.
3. The conclusions match the introduction.
4. The report has *one* key message.
5. All theory described is relevant for the rest of the report.
6. All presented results are relevant for the conclusion.
7. All figures are relevant for the conclusion.
8. The results *support* the conclusion.
9. *All conclusions* are well founded.
10. *All premises* are well founded.
11. The transition between chapters is fluent and natural.
12. The writing style is fluent (no complicated sentences, easy to read).
13. The writing style is efficient (no unnecessary sentences as "I'm now going to describe the results").
14. The writing style is formal.

Of course this list has to be merged with the list focusing on the *content.* For example, the list above doesn't say much about the quality of the research question. The research question should be:

- Connected to the experiment
- Answerable
- Exact
- Complete
- Compact

(See also my publication on the PEMFC experiment[2])

Overall I think the new checklist proved very useful and the new approach to the reports with a focus on the *purpose* of the report has been quite successful. Of course the content should be judged as well and is at least as important as the structure of the report, but by letting the students focus on *why* they write something, the content is usually improved as well: it is impossible to found conclusions with bad results.

Hoe schrijf ik een artikel?

Het kerndoel vaststellen

Bij het schrijven van een artikel moet je je realiseren dat je maar één kernboodschap kunt overbrengen. Je kunt dus ook maar één hoofddoel hebben. Begin daarom altijd met de vraag:

Wat wil ik bereiken met dit artikel?

In de wetenschap zal een artikel vrijwel altijd als doel hebben om lezers te **overtuigen** van de conclusies die de auteur trekt. Een wetenschappelijk artikel wordt immers pas gepubliceerd wanneer de auteur overtuigd is van zijn eigen resultaten. Ook op het practicum is *overtuigen* meestal het hoofddoel.

Echter, wanneer een experiment geen duidelijke resultaten heeft opgeleverd en er te weinig tijd is om het nog eens over te doen zul je bij het practicum soms een artikel schrijven wat vooral probeert de volgende groep studenten uitvoerig te **informeren** over de opzet van het experiment en eventuele fouten die gemaakt zijn. Zij kunnen dan verder met jouw experiment en op die manier komen ze dan hopelijk wel tot een goed resultaat.

Het doel van elk hoofdstuk: op weg naar samenhang

Over het algemeen zijn studenten goed bekend met de verschillende onderdelen die in een artikel terug komen. Je begint met een inleiding, dan volgt een stuk over de theoretische context, de methodiek, de resultaten en ten slotte de discussie en conclusie.

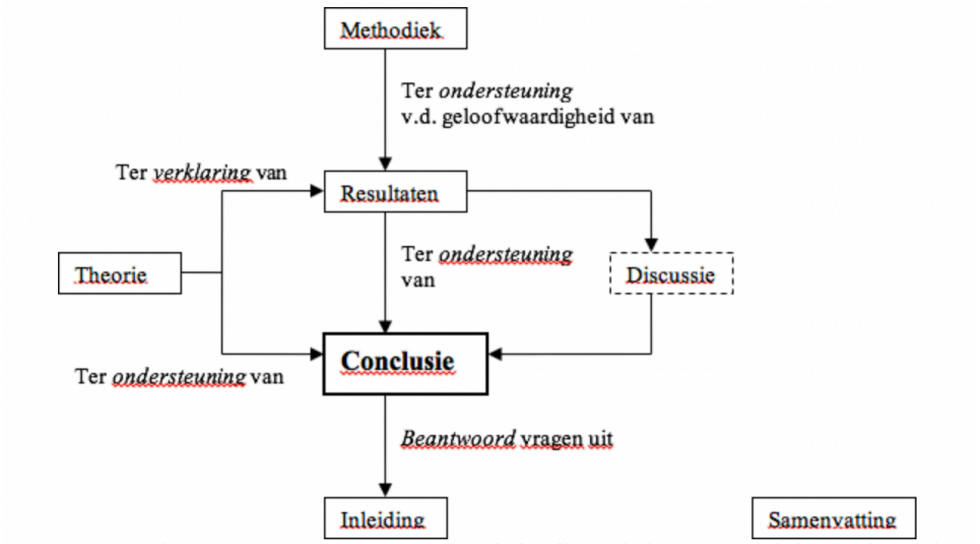
Probleem is: hoe maak je deze onderdelen tot één samenhangend geheel?

Foute aanpak: beginnen bij het *begin*: de inleiding. Dat is niet handig! Je schrijft lineair (van begin naar eind) en dan is het vrijwel onmogelijk om de lezer het gevoel te geven dat je *conclusie* centraal staat.

Goede aanpak: begin bij het *eind*, de conclusie. Immers, je wilt je lezer overtuigen dat jou conclusie klopt. *Daar* draait je artikel om. Tip: **maak eerst je figuren** (resultaten) en schrijf er een (volledig en duidelijk) onderschrift bij. In dit onderschrift beschrijf je wat er in het figuur staat en (kort) welke conclusie je daar uit kunt trekken. Hierdoor analyseer je je resultaten goed en heb je gelijk vastgesteld waar je artikel om draait.

Bij het schrijven van een artikel moet je als auteur voortdurend het **doel** van wat je schrijft in je hoofd hebben. Dat doe je bij elk **hoofdstuk**, maar ook bij elke **alinea** en zelfs bij elke **zin**. Een paragraaf waarvan het doel niet duidelijk is, is een overbodige paragraaf! En datzelfde geldt voor een zin waarvan het doel niet duidelijk is: die leidt tot irritatie bij de lezer. In het ergste geval slaat een lezer hele stukken tekst over. Lezers zijn lui, dus schrijf compact en efficiënt.

In de onderstaande figuur is de structuur en de samenhang van een artikel weergegeven.



Figuur 1 – Algemene structuur van een artikel. Elk artikel is uiteindelijk opgebouwd rondom de conclusie. De resultaten dienen (via de discussie) ter ondersteuning van de conclusie.

De kern van het artikel is de *conclusie*. Hier draait het hele artikel om.

Om de conclusie te ondersteunen kunnen de *resultaten* worden gebruikt. Ook de vooraf bekende *theorie* moet de conclusie ondersteunen.

De presentatie van resultaten en de *discussie* van resultaten worden vaak gescheiden, maar bij uitzondering is het soms handiger om deze te mixen.

Om de resultaten te verklaren wordt *theorie* gebruikt waarvoor al eerder bewijs is gevonden. Hoeveel theorie beschreven moet worden, hangt af van de *doelgroep*. **Het doel van de theorie is nooit om te laten zien hoeveel de auteur af weet van een bepaald onderwerp!** Pas hiermee op, want dit is iets wat vaak wel gebeurt in artikelen die op het practicum worden geschreven.

De gebruikte methode wordt beschreven met een tweeledig doel:

- Ter ondersteuning van de geloofwaardigheid van de resultaten.
- Teneinde andere onderzoekers in staat te stellen een experiment te herhalen.

De inleiding van een artikel dient ter *introductie* van het onderwerp. Een lezer moet in staat zijn om alléén de inleiding en de conclusie te lezen (dit is wat de meeste lezers namelijk doen). **Zorg er dus voor dat de samenhang tussen inleiding en conclusie goed is!** Alle vragen die in de inleiding gesteld worden moeten in de conclusie beantwoordt worden. En voor alle antwoorden die in de conclusie worden gegeven moet een vraag worden gesteld in de inleiding!

In de *samenvatting* komen de belangrijkste vragen uit de inleiding en de belangrijkste conclusies naar voren. Een samenvatting is zelden langer dan een paar regels!

Het kerndoel van dit artikel

Hopelijk heb ik je kunnen overtuigen van de noodzaak om steeds na te denken over het doel van wat je schrijft. Dat is de belangrijkste boodschap: stel jezelf voortdurend de *waarom* vraag.

De volgorde waarin je schrijft is belangrijk, maar er is geen vast stramien voor. Wat echter in ieder geval noodzakelijk is, is dat je je resultaten vooraf analyseert en je conclusie vooraf formuleert. Anders ken je je hoofddoel niet.

Het kan ook zeer handig zijn alvast figuren te maken met een uitgebreid onderschrift en deze met je assistent te bespreken voor je überhaupt met schrijven begint. Dan weet je zeker dat de kern van je artikel goed staat.

In het volgende hoofdstuk worden enkele richtlijnen gegeven voor de volgorde van het schrijven van een artikel. Bedenk wel: dit zijn slechts richtlijnen. Uiteindelijk kies je zelf wat het handigst is.

De volgorde van schrijven

Hieronder volgen enkele richtlijnen voor het schrijven van je artikel (vrij vertaalt naar de "Weitzlab Guide to Good Paper Writing").

Conclusie

De conclusie is de kern van je artikel. Schrijf deze dus eerst! Dit kan echter alleen als je de *resultaten al hebt geanalyseerd* voor je begint te schrijven. Zorg dat je conclusie maximaal een paar regels bevat.

Belangrijkste punt van je artikel

Een kort artikel (Science, Nature, practicum) kan maar één kernpunt bevatten.
In *een lang artikel* kan een auteur een extra punt maken. Echter, een artikel kan zelden meer dan een paar punten bevatten. En elk artikel moet één duidelijk kernpunt hebben.

Introductie

Schrijf dit pas *na* de conclusie. Denk aan de samenhang van beiden, zoals eerder genoemd! De conclusie geeft antwoord op vragen die gesteld zijn in je inleiding.
Maak duidelijk dat het (fysische) onderwerp van je artikel waar je conclusie betrekking op heeft *interessant* en *belangrijk* is (het liefst zowel wetenschappelijk als maatschappelijk gezien).
Een hoop is al bekend (in de literatuur)
Maar het punt waar jouw conclusie om draait nog niet. (Dit is op het practicum natuurlijk niet altijd zo, maar presenteer het in elk geval wel zo!).

Nieuwe paragraaf. Dit punt is precies waar jouw artikel over gaat.

Figuren

Nadat je je conclusie hebt geschreven weet je wat je kernpunt is.
Nu kun je de figuren uitzoeken die nodig zijn om je conclusie te *ondersteunen*.
Voeg een beschrijving en nummering aan de figuren toe.
Eerst je figuren uitkiezen en dan pas je resultaten beschrijven zorgt er voor dat het schrijven makkelijker wordt.
Bediscusieer alle figuren in de tekst. Beschrijf:
Wat je ziet in het figuur (een droge beschrijving)
Wat dit betekent (interpretatie)
Waar je deze beschrijving en discussie van je resultaten doet, hangt af van je artikel. Meestal zul je bij je resultaten in elk geval een *beschrijving* geven van wat er in de figuren staat, en komt de *interpretatie* in een aparte paragraaf of een apart hoofdstuk.

Leesbaarheid

Alle artikelen moeten een verhaal vertellen en moeten interessant zijn voor de lezer.
Gebruik de *tegenwoordige tijd*. Dit maakt het artikel directer.
Gebruik geen ( ) in de tekst. Iets wat tussen haakjes staat, is blijkbaar niet belangrijk en hoeft er dan ook niet te staan.
Gebruik geen bijv. Dat is lui schrijven.

Koppelzinnen

Koppelzinnen koppelen verschillende stukken tekst aan elkaar. Ze beginnen een nieuwe paragraaf en introduceren een nieuw concept. Deze zinnen zijn *extra belangrijk* voor de leesbaarheid van een artikel. Gebruik daarom nooit zinnen als:
"Nu ga ik dit en dat beschrijven." Hoewel dit vaak gebeurt in een artikel, is het een totaal overbodige zin. Begin gewoon met wat je gaat beschrijven.
"Dit en dat is de afgelopen jaren een belangrijk onderwerp (in de wetenschap)." Dit, of een variant hierop, is vaak de eerste zin van een artikel. Toch is het een overbodige zin: als je onderwerp niet belangrijk zou zijn, zou je er niet over schrijven.

References

[1] Unknown author, *"Weitzlab guide to good paper writing"*, Harvard university website, http://www.seas.harvard.edu/weitzlab/paper_guide.pdf, 2008

[2] Joris van Leeuwen, *"Analyzing the role of the practicum assistant in the context of setting up a PEMFC experiment for second year physics students",* Vrije Universiteit Amsterdam, 2009