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Published online: 19 Apr 2018.

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Unpacking challenges of data commentary writing in master's thesis projects: an insider perspective from chemical engineering

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ABSTRACT

Background: Data commentary, in-text comments on the visual presentation of data, is acknowledged as a central aspect of academic writing in many engineering disciplines. At the same time, it is a feature that has been shown to be challenging for students. One of the genres in which data commentary plays a significant role in many engineering disciplines is the master's thesis. Comparatively little research has been done on the process of master thesis supervision, and combining the study of data commentary and master's thesis supervision is therefore particularly interesting.

Purpose: This study explores the challenges of data commentary writing through interviews with master's students and thesis supervisors of chemical engineering.

Sample and method: Master's students at a Swedish university were invited to participate in a workshop about the writing of data commentary. Nine master's students and five supervisors were interviewed about what is difficult and important about writing data commentaries in their discipline as well as about decisions made in data commentaries written by the students. The interviews were divided into a semi-structured and a discourse-based part.

Results: Our results indicate that data commentary comes with a variety of challenges. Among the most difficult and important aspects are selection of content and clarity. The study also indicates a close connection between data commentary and disciplinary learning in chemical engineering, suggesting that highlighting data commentary in the teaching of master's thesis writing will be time well spent.

Conclusions: In order to make the teaching and learning of data commentary effective in the context investigated, we propose that important measures are: the development of a shared metalanguage among students and supervisors, a genre approach, and collaboration between engineering and communication faculty.

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Introduction and background

The in-text commentaries accompanying visual displays of results (tables, figures, etc.) in academic texts are often referred to as *data commentaries* (Swales and Feak 2012; 139). Data commentaries play a central role in many disciplinary genres, partly because the main argument often unfolds as the authors move between visual displays and running text. Poe, Lerner, and Craig (2010, 115), for example, argue that 'visual representations of data are the work horses of arguments' in biotechnology writing, and Curry (2014) demonstrates how three research groups from different engineering groups use visual material as their point of departure for identifying results and for conceptualising and drafting the scientific story of their research papers. In the end, Curry shows that visual material is essential in text and knowledge production in several engineering disciplines. The importance of visual material is also highlighted through studies of graphing, the ability to interpret and produce graphs. For instance, Nixon et al. (2016) describe graphing as an essential aspect of thinking like a physicist.

The centrality of data commentary in science and engineering writing is also indicated by the fact that most technical communication as well as academic writing books today give basic guidance to data commentary and data visualisation. At the same time, several studies point out that text books do not provide comprehensive guidance for learners (Poe, Lerner, and Craig 2010; Wolfe 2015) and that data commentary remains problematic for novice writers. Curry (2014), for instance, calls for a broader focus on multimodality in both research and writing instruction, the main reason being that visual material tends to play a crucial role in the organisation of the storyline, and Poe, Lerner, and Craig (2010) argue that text books often place too much focus on surface features, such as language accuracy, and too little on argumentation and selection of data. Further, Sancho Guinda (2012) discusses Spanish second-year engineering students' difficulties when commenting on data in a number of pre-selected charts and chart types, and argues for a discipline-specific, moves-based approach to data commentary instruction (Sancho Guinda 2012, 373; cf. Swales 1990; Swales and Feak 2012), without going into detail about how to organise such instruction.

In addition to these studies, our own experience from teaching academic writing to PhD students at universities of technology tells us that the combination of visualisation and data commentary tends to be central when presenting and ordering results in certain disciplines. One such discipline is chemical engineering. Many of our PhD students in this discipline have described that the composition of an article often starts with decisions about what figures to include, how to order them and how to build an argument around the order chosen. However, this understanding and description of the role of data commentaries stand in quite sharp contrast to how some students present data commentaries in their master's theses. For instance, in a corpus of master theses within chemical engineering collected for a previous study (Nordrum and Eriksson 2015), we found that some students consistently referred only generally to the results displayed without further commenting on them, as in the following example:

> The Coefficient of Variance is calculated from a cross section 11 m from injection to compare the rheology models. The results from the simulations with a single injection point are given in Figures 3–17.

Here, the authors refer to 15 figures without further commentary. The authors thus rely on the reader understanding what they consider important in these figures. To us this example

was somewhat surprising, both from the perspective of disciplinary writing and the perspective of disciplinary learning. In the master's thesis, students are to demonstrate in-depth disciplinary knowledge as well as their ability to plan, perform and present research-based types of projects. Rhetorically, the authors of the excerpt have not taken the opportunity to highlight what they consider important in Figures 3–17, and it is hard to know what results are particularly relevant considering the research question they have asked.

In this study, we investigate students' and supervisors' perceptions of data commentaries in master's theses in chemical engineering. We start from the assumption that data commentary in results sections is a central subgenre within master's theses and journal papers in chemical engineering (cf. Curry 2014; Poe, Lerner, and Craig 2010; Sancho Guinda 2012) and that it is therefore of particular rhetorical and disciplinary value. Our study explores three research questions:

> What do students and supervisors of chemical engineering perceive to be difficult when working with data commentaries in master's theses?

> What do students and supervisors of chemical engineering perceive to be important when working with data commentaries in master's theses?

> Can any pedagogical challenges related to data commentary be found in the context investigated, and if so, what are those challenges?

The research questions are explored in interviews with students and supervisors carried out before and after a workshop on data commentary writing.

Master's thesis supervision

Comparatively little work has been done on master's thesis supervision, as most work on supervision in higher education concerns doctoral students. Some of the aspects of master's thesis supervision that have been studied are text negotiation and discipline (Dysthe 2002; Dysthe, Samara, and Westrheim 2006) and perceptions of feedback (de Kleijn et al. 2013, 2014). In a recent study, Harwood and Petrić (2017) address supervisors' and international students' experience of the supervisory process in the UK. The study is set within the humanities and social sciences and highlights the considerable differences in approaches, attitudes and emotions that students and supervisors experienced and also the great variation in practices of individuals and policies of institutions. Harwood and Petrić (2017) note that comparatively little work has been done on master's thesis supervision, particularly on processes, which underlines the need for more research on issues such as what perceptions master's students bring into the master's thesis project.

An important aspect of master's thesis writing is that, during the writing of the thesis, the negotiation of writing does not necessarily involve a writing expert. Instead, this is typically a negotiation between students and disciplinary experts. Research has shown that disciplinary experts may struggle to explicate their knowledge about writing (Blåsjö 2011; Geisler 1994; Jacobs 2007), and that there can be a discrepancy between how students perceive comments from disciplinary experts and the intentions of the disciplinary experts (Pelger and Sigrell 2016). For example, in a study of supervisors' comments on 44 biology and molecular biology master's theses from a major Swedish university, Pelger and Sigrell (2016) show that while students perceived feedback as mainly addressing language and style, disciplinary experts intended to emphasise both content and discourse organisation. We therefore argue

that it is necessary to know more about how students and supervisors perceive and talk about the writing of their disciplinary genres in order to isolate both writing and content-related challenges.

Teaching and learning of genre writing in science and engineering

One of the most common approaches to analysing and accounting for writing in a specific discipline is a moves-based analysis (Swales 1990; Swales and Feak 2012), which is referred to as a 'genre approach' in this study. Such an analysis investigates and describes what communicative functions are used by writers in a particular genre. In the analysis, texts are divided up into sections on the basis of what communicative function (or move) the section performs. This type of research stems from Swales' (1990) work on the introduction section of scientific journal articles. In this work, Swales identified three main moves in introductions across disciplines: (1) establish a territory, (2) establish a niche and (3) occupy the niche. To exemplify how these functions are represented in text, the second move often involves the authors identifying what type of research is missing or incomplete within the discipline and, in the third move, the authors introduce their own research and how it, in one way or another, addresses what is regarded to be missing. As an extension of Swales' work, numerous scholars have developed discipline-specific moves analyses for various disciplines, for example computer science (Posteguillo 1999), biochemistry (Kanoksilapatham 2005) and mathematics (Kuteeva and McGrath 2015). Although these studies do not aim specifically at pedagogical application, the pedagogical value of the developed framework tends to be stressed.

Genre analyses inform numerous academic writing courses in higher education. Often, such courses are run by writing experts, but there are also examples of how genre analyses are used in projects involving collaboration between writing experts and disciplinary specialists. One of the best examples of such an approach is the *Write like a chemist* project by Stoller, Robinson and colleagues (Robinson and Stoller 2007; Robinson, Stoller, and Jones 2008; Robinson et al. 2008; Stoller et al. 2005, 2006; Stoller and Robinson 2013). The key task of this project was to develop moves structures for a number of academic genres in chemistry (journal articles, abstracts, proposals and posters) (Stoller and Robinson 2013, 46) and use this structure to develop pedagogical materials (Robinson et al. 2008).

The *Write like a chemist* project is of particular interest for the present study because it involves analyses of results sections in journal articles in chemistry (Stoller and Robinson 2013). However, the moves and sub-moves structure was primarily developed to give students a good overview and starting point and did therefore not account for all variation between subfields of chemistry (Stoller and Robinson 2013, 48–50). In a study from 2015, we presented a slightly more detailed moves structure model of data commentaries in results sections of journal articles and master's theses in chemical engineering (Nordrum and Eriksson 2015), and this structure informed the workshop on data commentary reported on in this study (see the section *Workshop design* for details).

Method and material

This study is based on interviews with master's students and their supervisors collected before and after a workshop about data commentary writing for master's students in chemical engineering. The workshop was given by the authors. Here, we first provide details about

the participants and the timing of the workshop, next we explain the interview procedure for student as well as supervisor interviews, then we give an overview of the workshop design, and finally we present the data analysis.

Participants

The students participating in this study were master's students of chemical engineering who were in the process of finishing their master's thesis at a Swedish research university. Most students were completing their last term on a five-year programme towards a degree of Master of Science of Engineering, Chemical Engineering, while some had studied the first three years at other universities and were working towards a Master of Science. Studies in chemical engineering typically involve topics such as the modelling and design of chemical processes, fluid mechanics and heat transfer. In the context investigated, there is often also some overlap between chemical engineering and applied chemistry, as students for instance study analytical chemistry. After completion of the master's programme, students can take up a career within academia or within industry.

The students were recruited through an invitation to master's students of chemical engineering to attend a workshop on academic writing with a focus on data commentary. The invitation was sent by one of the chemical engineering supervisors to students writing their master's thesis at the department of chemical engineering during the spring of 2015 and the spring of 2016. The student data were collected on two separate occasions: one workshop was delivered in 2015 with seven students attending, and one in 2016 with four students attending. Nine of these eleven participants could attend all activities (the workshop + three interviews, see the section *Interview procedures*) and were included in the study.[1] Because students were invited to participate, the sample of students is not necessarily a representative sample of the student cohort. Nevertheless, the students who participated belong to the group of students we wanted to approach, and the student sample is therefore well suited for an exploratory study. In 2015, 25 students were registered as master's thesis students of applied chemistry, and in 2016, 31 students were registered. Some of these students did their master's thesis abroad or in other cities, and it is therefore not fully clear exactly how many students could potentially have attended the workshops.

According to a background record filled in prior to the workshop, the students had experience of writing in their discipline, primarily through lab reports and their bachelor's thesis, but they had not had any specific training in disciplinary writing via technical communication courses or communication modules embedded in engineering courses (also known as Integrating Content and Language (ICL) (Gustafsson and Jacobs 2013). All students were non-native speakers of English, and the context is what is sometimes referred to as an English-medium instruction (EMI) context. It is worth pointing out, as do Harwood and Petrić (2017, 2), that language is only one characteristic that distinguishes the students in this type of educational context. We are aware that features such as language and educational background obviously affect students' experience of their current education, but we have not divided our cohort into subgroups but focus on the perceptions represented in the context investigated.

In addition to the students, five supervisors were interviewed. These were all supervisors of at least one of the students participating in the workshop. The supervisors had varying degrees of experience, with one supervisor still being a PhD student while the four others

were senior researchers. None of the supervisors interviewed had English as their first language.

Interview procedures

The study is based on interview data because interviews are useful for the collection of descriptions of people's experience of particular situations or activities (Kvale 2007, 10–11). Two student interviews were carried out on the day of the workshop, one before and one after the workshop. The second interview primarily focused on what the students had worked on and changed during the workshop. A third student interview was carried out a few weeks after the workshop. The supervisor interviews were conducted after the students had completed the third interview and had handed in the final draft of their master's thesis. In this paper, we use the supervisor interviews and two of the student interviews: the pre-workshop interview (referred to as interview 1) and the third student interview (referred to as interview 3). These interviews were used because they were exploratory and contained questions relevant for the research questions investigated here. All participants gave their consent to participating in the study.

   All interviews were divided into two parts: a generic, semi-structured part and a semi-structured, discourse-based part (Appendix A–C) (Moore and Morton 2017; Odell, Goswami, and Herrington 1983). The generic part was primarily used to collect the participants' general perception of what is difficult and important about data commentaries. These questions therefore primarily addressed the first two research questions, but the information about what the students and supervisors find difficult and important can obviously also have consequences for the pedagogical strategies suggested. The discourse-based part was used to collect text-based examples of what the challenges of writing data commentaries may be. Discourse-based interviews are interviews based on talk around a written artefact. Odell, Goswami, and Herrington (1983, 226) explain that one of the benefits of a discourse-based approach is that it can 'tell us about the tacit knowledge that they [the writers, in our case also the supervisors] bring to writing tasks'. Since we wanted to understand students' and supervisors' perceptions of data commentaries and the challenges of writing data commentaries, the discourse-based parts were considered a good complement to the semi-structured parts, particularly when it comes to understanding what supervisors see as essential when writing data commentaries. As pointed out in the introduction, content supervisors may have problems explicating their knowledge about writing, and the discourse-based interviews therefore gave additional opportunities to find out how supervisors reason about text. In addition, the text-based part made it possible to compare how students and supervisors talked about the same piece of text.

   For the discourse-based part of the student interviews, the students were asked to bring drafts of one or two figures or tables and their accompanying data commentaries from their ongoing thesis work. On the basis of a few questions, the students were then asked to comment on the drafts, for instance about what they wanted to convey with the figure, what the most important points were and who they considered to be their reader (see Appendix A and B). In the discourse-based supervisor interviews, the supervisors commented on one or two data commentaries written by a student they had supervised. These text excerpts were brought by the interviewer. The supervisors were asked to elaborate on matters such as whether or not the combination of figure and data commentary worked, and, if it did not,

what they would like to change (Appendix C). The supervisor interviews were carried out after the students had handed in their final drafts and defended their thesis and did not affect the supervision or grading of the text. The text excerpts were however not taken from the final draft but from the draft that the students brought to the follow-up interview a few weeks after the data commentary workshop.

The first set of student interviews lasted between 9 and 16 min and the second set between 8 and 38 min. The reason for the vastly different lengths of the second interview was that some students had a lot more to say about data commentary than others, but also that there was significant variation in the level of detail with which they described their own commentaries.

The supervisor interviews were between 22 and 40 min long. The difference in length was partly due to one interview being considerably longer than the other interviews (the second longest supervisor interview was 31 min) since the supervisor in this interview had supervised two students and the discourse-based part therefore involved discussions of two data commentaries.

The great majority of the interviews were carried out by the authors (13 out of 18 student interviews and all the supervisor interviews), but in the 2015 run of the workshop, two senior researchers with extensive experience of performing interview studies were brought in to speed up the pre-workshop interview process and to avoid students having to wait for a very long time before the workshop could start. Three of the seven pre-workshop interviews (interview 1) were done by these two researchers. These researchers were not writing experts, and it is possible that this affected the results of the interviews, particularly the discourse-based parts, but our analyses have not indicated that the students gave different answers in these interviews. In addition, two of the post-workshop interviews (interview 3) in 2015 were conducted by another senior researcher with expertise in writing.

Workshop design

The four-hour workshop consisted of three main parts, of which the first part was the longest. Here, the students were introduced to the model of rhetorical moves developed for results figures and tables within applied chemistry and to the UAM corpus tool (O'Donnell 2009), which was used for text analysis in the workshop (for a more detailed account of the model and the corpus tool, see Nordrum and Eriksson 2015). As shown in Figure 1, the three main moves of the model are *background*, *presentation of visual* and *comment on result*. These moves then contain several submoves or steps (Swales and Feak 2012, 331). It is not necessary to use all moves and submoves in single data commentary. For example, many data commentaries do not include a background move, and if they do, only one of the sub-moves *procedure-method*, *disciplinary-knowledge* or *comment-on-choice-of-presentation* is usually present. In the workshop, the students were given an overview of the moves model, and a few examples were analysed and colour-coded by means of the UAM corpus tool in order to show how moves can be distributed in a particular data commentary.

The second part of the workshop highlighted the move *presentation of visual*. The students analysed different ways of introducing a figure in the text (e.g. Figure 1 *shows something* vs. *something is shown in* Figure 1) and compared published journal articles and master's theses.
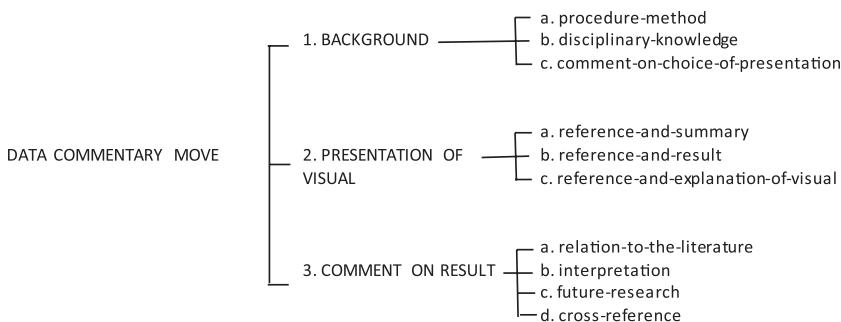
Figure 1. A moves model of data commentary on result-reporting visuals in chemical engineering. The moves should be read from left to right. An example of a data commentary from a master's thesis in chemical engineering could be a background move realised by submove 1a) reminding the reader of how the data presented in the visual was obtained, followed by a presentation-of-visual move realised by submove 3a) providing a reference to the figure and the main result (e.g. *Figure 1 shows that there is an increase in* (…)), and last a comment-on-result move realised by submove 3d) giving a cross-reference to where in the master's thesis the result in the visual is discussed (e.g. *This increase will be further discussed in Section 4.2*).

The third and final part was relatively short. It involved students' revisions of data commentaries from their own theses, which they had been asked to bring to the workshop.

Data analysis

The interviews were recorded and transcribed verbatim and then analysed by means of two main procedures.[2] First, the responses from the generic part of the interviews (student interview 1 and 3 and the supervisor interview) about what is difficult and important were sorted into a construct table (Miles, Huberman, and Saldaña 2014, 171). This procedure was used to address the first two research questions. Construct tables are suitable for investigations of specific variables, in this case 'difficult' and 'important', and can be used to provide an overview of perceptions expressed by the students and the supervisors. Author 1 developed the initial codes of the construct table and then both authors refined the table iteratively and finalised the coding. The coding was performed manually directly in the transcribed text files. Data from the discourse-based parts of the interviews were later added to the construct tables provided that the comments were general comments rather than comments about specific passages of a text.

Second, the transcripts of the discourse-based interviews were annotated for topic themes by means of open coding as described by Miles, Huberman, and Saldaña (2014). This analysis primarily aimed at addressing the third research question, and provisional topic themes and orientations around challenges of pedagogical concern were therefore developed. For example, passages in which the supervisors commented on content-related misunderstandings or mistakes were noted down as 'disciplinary content mistakes'. These codes were then refined as both authors independently went through the transcriptions to find recurring themes. Finally, a process of moderation was used to arrive at a consensual analysis.

Table 1. Students' and supervisors' perceptions of what is difficult about writing data commentaries (N students = 9, N supervisors = 5).

Perceptions of what is difficult	N (students), interview 1	N (students) interview 3	N (supervisors)
Aspects of mechanics (language, repetition, layout)	2	2	4
Selecting material	5	2	2
Understanding and/or describing complex phenomena	3	1	1
Commenting on premises/unexpected results	1	1	1
Expressing concepts clearly	1	3	1
Using appropriate structure (order of text)	0	0	1
No difficulty identified	0	3	1

Results

The presentation of results is divided into two main parts. In the first part, we address the first two research questions: the students' and the supervisors' perceptions of what is difficult and what is important in data commentary. This account gives an overview of how the topics are perceived by the students and the supervisors. The second part presents pedagogical challenges of data commentary in the context investigated (research question 3). The results in this section are based on the discourse-based parts of the interviews. On the basis of analyses and comparisons of the student and supervisor interviews, themes of pedagogical challenges were developed from recurring challenges noticed in these conversations.

What is difficult and important

Table 1 presents a thematic overview of the answers to what is difficult when commenting on result-reporting visuals in chemical engineering. The results have been collected from student interview 1 (pre-workshop), student interview 3 (post-workshop) and the supervisor interview. As can be seen, no themes were mentioned by all participants, which indicates a certain level of variability and complexity in terms of how students and supervisors experience the writing of data commentaries. In our qualitative analysis, two themes, *selecting material* and *aspects of mechanics*, emerged as salient both in terms of their distribution across students and supervisors and the comments made in connection with these themes.

The comments on selecting material were of two types. The first type concerns selection of what and how much to write about a certain visual, as illustrated in the following student and supervisor comments:

Student 9: Hmm it is a bit difficult. You are afraid that you write too much … so it becomes almost too clear. Don't know if that is good. So it is probably knowledge … you, you think that someone else will understand directly, but you are afraid of writing too much.

Student 7: yes it may be difficult to actually say everything I wanted to say because of course we don't want the report to be extremely long, so I may have some difficulties keeping concise.

Supervisor 5: In my experience the writing is not difficult in itself, but selecting what to write. Too much and the wrong things. Beginning with describing what is already described in the visual rather than describing what is important.

All three quotes indicate that selection is difficult, in one way or another. It is worth noting that the comments are fairly brief, and overall, both the students and the supervisors had difficulties expanding on what may be difficult when asked this general question. For instance, the students did not comment on the type of information they typically decided to include or exclude in the commentary, or how such decisions were made.

The second type of selection difficulty concerns how to determine whether a result should be included among the results presented visually at all. This concern surfaced in one supervisor interview:

> *Supervisor 2:*   The thing about picking results is really difficult, really. Students have not yet developed the eye for knowing what a good result is.

The supervisor here seems to assume that the skill of choosing appropriate results for visual presentation will develop with academic maturity and cannot be expected from master's students.

The two categories of comments on selection support Poe, Lerner, and Craig's (2010) claim that selection is an important theme in the teaching and learning of data commentary writing and suggest that selection should be addressed from two angles: (1) selection of what to comment on after the visual has been chosen, and (2) selection of which results should be displayed visually and commented on.

A second observation from Table 1 is that both the supervisors and the students mentioned issues of mechanics as being problematic. The supervisor comments concerned appropriate layout and language as shown by the following comments:

> *Supervisor 1*:   The most common mistake is that they do not have proper units, axes are missing. They have not reflected on how long the axes are. Cosmetics.
> *Supervisor 2*:   They have difficulties achieving a proper layout of the text.

It is possible that the supervisors' focus on mechanics reflects that they often meet mistakes of this type and that they therefore regard mechanics as an important category to focus on in their supervision.

In terms of the influence of the workshops, the data collected is not large enough to establish changes in student behaviour and understanding, but we note that some students explicitly stated that the workshop made them think more carefully about the type of information to include in a data commentary and how to organise the information:

> *Student 3*:   Well, you think a lot more about things like, perhaps you try to start with some background information, if that is what you want, and then you try to put that first in a nice way and then you move to making a reference to the figure and then you try to be a bit more detailed.
> *Interviewer*:   Yes what do you mean by detailed?
>
> *Student 3*:   That it is more clear [indicates steps] 'now it is background, now I explain what you see, now I discuss'.
> *Student 9*:   [talking about what to put in a data commentary] what first you sort of make a reference in the literature eh background description of the figure and then to describe what's in the figure and the most obvious results. Especially the ones that you want to show to the readers. And then some sort of implications of the results.

In addition, student 4 stated that 'before it [data commentary] was just vaguely described in my head but in the workshop you really made it clear what to write'. Our analysis thus

Table 2. Students' and supervisors' perceptions of what is important about writing data commentaries (*N* students = 9, *N* supervisors = 5).

Perceptions of what is important	N (students) interview 3	N (students) interview 3	N (supervisors)
Clarity (of explanation)	5	8	4
Using appropriate layout	4	1	0
Commenting on implications	0	3	2
Selecting material	1	4	3
Comments on assumptions and background features	1	1	1
Clear in-text references to the figure	1	1	1
Mentioning deviations or errors in the procedure	1	1	0
Integration of text and figure	0	2	2

indicates that the genre-based instruction gave some guidance to the problem of selection of information in the data commentary.

Table 2 presents a thematic overview of the answers to what the students and the supervisors considered important in data commentaries in chemical engineering. Just as we saw for 'what is difficult', there is a wide range of themes and limited reoccurrence between themes, indicating variability and complexity in the perception of what is important in writing data commentary among both the students and the supervisors. In the qualitative analysis, the theme *clarity of explanation* emerged as the most salient theme in the student and supervisor comments, both in terms of comments and distribution across the participants (Table 2).

The qualitative analysis of 'clarity of explanation' showed that in interview 1, the students had difficulties in elaborating what clarity means and comments were primarily of the following type:

Student 4: Ah, that you, like, to explain what you have achieved, you need to use the visual to make it more clear.

Student 8: Well you want the reader to understand the figure as well, so that all parts are included.

In interview 3, the students' comments were somewhat more specific, focusing on the importance of carefully explaining central results or aspects of the figure. In the words of three students:

Student 3: and then like it is very important that you spend time on trying to explain it [the visual] so that someone else can understand what it is that you see in the figure and what it is that is important and perhaps also what is strange or deviant.

Student 8: that you explain very carefully what the reader should see in the graph, what you want to show with the figure.

Student 2: after the workshop I have been thinking that one should try to explain … the figure to a blind person, for example things that are fairly obvious … so that one does not go too deep into things but say what can be seen in the graph and things like that – this bar is higher for this – well something like that … what is the most important result in a graph with a lot of information, kind of.

A possible explanation for the increased specificity of comments on clarity in interview 3 may be that the students had worked more with their texts in the final stages of their master's thesis project and thus refined their comments, but it is also possible that the genre-based

model in the workshop underlined the importance of bringing out the main result of a visual to the reader. Prior to the workshop, we suspect that it was less clear to the students that readers may have difficulties interpreting the visual. The supervisors elaborated on the topic of clarity in different ways. For example, one supervisor underlined the importance and value of understanding the figure without too much context:

> Supervisor 2:　All figures should be independent. Understand without having to go back to the text too much. The figure should be self-explanatory together with the figure caption.

Another supervisor instead highlighted the importance of graphical clarity as well as the combination of figure and text:

> Supervisor 4:　This is the way it looks and it looks this way because … present results in a clear way. Trends in data, accuracy of measurements. A combination of data presentation, a combination of designing a figure and writing a text.

In summary, the student responses from interview 1 indicate that clarity is perceived as an important yet somewhat vague concept that the students have difficulties elaborating on – at least prior to the workshop. The supervisors, in contrast, have more to say, but explanations differ, indicating that clarity is a multifaceted concept that deserves attention.

The discourse-based interviews: challenges of detail and focus, content learning and metalanguage

Through analyses of the discourse-based interviews, challenges related to teaching and learning were identified. Three themes based on recurring challenges emerged from the analysis: (1) challenges of detail and focus, (2) challenges of content learning and (3) challenges of using a shared metalanguage for data commentaries. As can be seen, the themes are quite different in character. The first one is a matter of being precise and detailed enough in the data commentary. We see that the supervisors easily question aspects of detail and focus, and although the material is fairly small, it is quite clear that this is something that students struggle with. It therefore seems important to familiarise students with negotiating detail and focus in their data commentaries. The second challenge reminds us that writing and disciplinary knowledge are closely intertwined. As data commentaries are central parts of master's theses in chemical engineering, some of the challenges concern disciplinary knowledge. Challenges of data commentaries do therefore not only pertain to layout, design and discourse organisation, but also involve disciplinary understanding. The third challenge is a challenge that the students and the supervisors seem to face when trying to talk about data commentaries. The lack of a shared metalanguage generates uncertainty and sometimes also misunderstandings when the students and the supervisors negotiate the data commentaries. The presentation below primarily contains examples from the supervisor interviews, but the themes partly emerged through comparisons of how the students and their supervisors talked about the same student texts.

Challenges of detail and focus

The discourse-based parts of the interviews added significant detail to what is difficult for students when writing data commentaries, particularly with regard to the category 'selection of material'. In the discussion of actual texts, the discourse shifted from difficulties in knowing

what information to select to statements about appropriate *levels* of detail in the data commentary. Typically, the gist of the comments was that a particular commentary was not necessarily inaccurate, but that important aspects shown in the graph were not sufficiently highlighted. Two categories of comments emerged:

- Details connected with formal aspects of the graph. Comments of this type concerned issues such as missing axes or missing information in figure captions.
- The focus and clarity of the data commentary. These comments concerned what the author wanted to say in the text, what should be highlighted and how it was expressed. This category also involved comments indicating that something was missing in the data commentary.

The first category primarily concerned issues of layout and design and was important to both the students and the supervisors. Several supervisors made specific comments about missing details in the figures. For instance, one of the supervisors explained that 'Well, this graph is … not particularly good … there is, there is no axis for the zero value … for concentration' (Supervisor 4), and one supervisor (Supervisor 3) mentioned the value of figure layout and visual design in establishing the credibility of a paper. Similar observations about the high prestige given to formal aspects of visual material have been made by Poe, Lerner, and Craig (2010, 138–139). It is possible that the supervisors' focus on layout works at the expense of discourse concerns, but it is also important to recognise that these issues clearly influence the overall impression of the text in this discipline. Above all, it is clear that the students need guidance in figure design, so that the values and variables most important from the point of view of the message are clearly presented.

The second subcategory of detail and focus concerned the focus and clarity of the data commentary. The main problem here was that the student data commentaries did not always highlight the most important point from the perspective of the research story of the entire thesis. The supervisors stated that students can be more or less precise in their selection and sometimes choose an unfortunate storyline, either in terms of highlighting a less interesting result or leaving out important results:

Supervisor 2:   Here he could have discussed to what extent this adjustment is correct … when is it well-adjusted and when is it not.

Supervisor 2:   but now that we have discussed it so I think I would want to have something about … like I said about concentration, a comment about these exchanges and concentrations being high enough … since that is not quite clear

The two quotes illustrate that the student data commentaries could have been developed to include more information. Another problem of focus and clarity concerns the order in which information was presented rather than lacking information. In these cases, the supervisors argued that certain passages should be moved or deleted, as illustrated in the following supervisor statement:

Supervisor 5:   well, no there are like no … there are many other explanations as well that have been combined with this data commentary … that do not really belong there … that could be put in a paragraph after this.

It is difficult for students to know what an appropriate level of detail is, and negotiating such issues is likely to be an important aspect of developing rhetorical awareness in the discipline. It is quite natural that aspects of detail and focus are difficult for students, as

the research story can be presented in different ways. It therefore seems particularly important for supervisors to be aware of this and be prepared to bring up such challenges in their supervision.

Data commentary and challenges in the learning of disciplinary content

The second specific challenge that emerged in the discourse-based interviews was disciplinary understanding. We indexed the following types of comments as problems of disciplinary learning: (1) comments that concern students' use (or misuse) of particular concepts, and (2) comments about students' contradicting disciplinary knowledge. In some cases, it was difficult to know, both for us and for the supervisors, whether a mistake was due to the student not fully understanding the concept or process described or not being able to express a particular idea or interpretation. In order to avoid exaggerating a category that is not within our field of specialisation, uncertain cases were categorised as issues of detail and focus (see the section *Challenges of detail and focus*) rather than disciplinary learning.

Some mistakes in the student texts can be attributed to the misunderstanding of a particular concept. For example, one of the supervisors commented on a student's use of 'absolute pressure' in the following data commentary:

> By plotting Equation (1.4) over an interval of moisture content in the bark at constant temperature together with the absolute pressure at the same temperature. Figure (1.2), it can be seen that the pressure for the isotherm will increase above the pressure for pure water at higher moisture contents

and said that:

> but absolute pressure I must say is a bit confusing (*Supervisor 3*)

and somewhat later, he continued:

> 'absolute' is not a good word here really …'absolute', I am not sure why he is using that … it is a vapour pressure it is … that is given by the equation that he has there … but 'absolute pressure', I am not sure why he would call it that (*Supervisor 3*)

The supervisor thus mentioned the use of 'absolute pressure' several times, which clearly indicates that this is a concept that the student has misused and misunderstood. This passage was revised before the thesis was submitted.

The second example comes from a passage that the student and the supervisor had discussed between the workshop and the supervisor interview, and it is a passage that the student had to revise:

> *Supervisor 1*:   It looks as if the fouling ratio is very low … and from her definition of fouling ratio, this is correct, but her thinking is completely wrong so she had to change this.

The example shows that the presentation of results connects very strongly with the use of particular concepts and underscores that data commentaries display disciplinary ways of thinking in the field of applied chemistry (Reynolds et al. 2012). The third example of the connection between data commentaries and problems related to disciplinary understanding comes from a student who discusses the relationship between a model and a result. The supervisor expressed concern about the student's way of reasoning about the term 'model':

> *Supervisor 4*:   [reading from the text, indicated by quotation marks] 'shows a simplified model', which it does not really do. It shows results from a model.

A bit further into the interview, the problem of not being able to distinguish between the model and the result from the model was highlighted in the following passage:

Interviewer: So one of the problems here is that she presents something as a model but in reality it is a result?

Supervisor 4:   Yes

Interviewer: Why do you think that she has written that this is a model rather than a result?

Supervisor 4:   It is quite possible that she thinks that these are the same thing …

One important point about this example is that it was only through the joint effort of a writing expert (the interviewer) and a content specialist (the interviewee) that the extent of the problems of the passage could be fully unpacked. From the perspective of the writing instructor, the passage seemed to be well written both in terms of structure and language. The content supervisor had not commented on the data commentary, and it was not until the supervisor was asked to do an isolated reading of the data commentary that he observed the weakness of the passage. In fact, this supervisor's final comment at the end of the interview was: 'There is a lot in here that I had not reflected on' (Supervisor 4). To us, this example therefore underlines the value of collaboration between content supervisors and writing experts. Most supervisors obviously have a great deal of knowledge about writing in the discipline, but they may not be able to unpack it and make it explicit to students.

Mediating master's thesis supervision of data commentaries: the value of a shared metalanguage

Although this study does not include direct student–supervisor interaction, the data indicate that students and supervisors partly lack a shared metalanguage for data commentaries, which may be a problem for communication and thus potentially for learning. One example of this being an issue is the supervisors' use of generic or metaphorical language when discussing the student texts. For instance, one of the supervisors talked about 'additional information' when referring to a sentence that both introduces the visual element in the text and includes a statement that summarises the content of the data commentary. Similarly, this supervisor talked about the need for a 'bow' to combine sentences or sections in a text, which we understood as a way of describing how a sentence or a section typically starts with information already known from the context (old-to-new information flow, Swales and Feak 2012, 31). A third example was a supervisor who talked about there being a need for 'putting more emphasis on something' without necessarily saying that this means that something should be highlighted in terms of where it is positioned in the rhetorical structure of the data commentary. Comments of this type can be more or less difficult for students to interpret and it is likely that students' abilities to address such comments differ.

The above examples illustrate language that is potentially challenging for students, but there are also a couple of examples that illustrate how insufficient metalanguage made it difficult for the students and the supervisors to adjust aspects of the data commentary in their discussions. The first example is from a student who followed the advice from the supervisor that she 'should start with what is most important' (Student 6). This is a phrase that both the student and the supervisor used in their respective interviews. What the supervisor really meant was that the student should avoid rendering the chronological structure of the research process when presenting the study in the master's thesis. The student, however, interpreted 'start with what is most important' as describing also how data

commentaries should be written. The effect of this advice was that the student followed it literally and presented the main result of the figure before even introducing the figure in the text, as can be seen in the following excerpt from the thesis draft:

> An experiment was performed with fresh alkali extraction. Initially, when the retentate flow pipe was below the surface of liquor in the feed tank, was the flux constant at 70 L/m^2 h. When the pipe was lifted above the surface of the solution in the feed tank, flux increased with time, as shown in Figure 4.6.

Here the student presents the result before introducing the figure by referring to it (Figure 4.6). Normally, the presentation of the main result comes after a reference to the figure. The example illustrates that it was difficult for the student to unpack what 'start with what is most important' meant in the specific context and that some students can be quite strongly influenced by their supervisors when structuring their text.

A final example comes from a student who in the interview and in the data commentary devoted a lot of attention to explaining unexpected results or results indicating that something in the experiment had gone wrong. This example suggests that the student had some problems understanding what to highlight in the data commentary. Comparisons of the student and the supervisor interviews and analyses of the student's texts show that the student did in fact put too much focus on the unexpected results and did not comment on the main results of his study. In the third interview, the student asked the interviewer: 'Do I have to comment on what is obvious, which is as expected?' (Student 5). Here the point is that what is expected is also the student's main result: the visual that the student comments on shows that the student's method is acceptable, and this fact should be the first result commented. However, in the data commentary draft that the student brought to the interview, only the unexpected results were addressed. In a discussion of the same passage in the supervisor interview, the supervisor stated that the main result should be commented, and when asked about whether or not the student may think that the unexpected result is the most important result, he explained:

> *Supervisor 2*:   Well, he may think that it is [the most important thing] in the sense that this is not what it is usually like.

Here it is quite likely that the student and supervisor would have benefited from a shared idea of what needs to go into a data commentary or at least a common language to discuss the type of information that goes into the commentary and how such information is typically organised.

All in all, our analyses indicate that students struggle to find appropriate levels of detail in their data commentary, that students make content mistakes that can be identified through detailed reading, and that students and supervisors do not share a metalanguage to talk about data commentary at appropriate levels. To us these results give important information about what to consider when addressing data commentary in teaching and learning. We therefore synthesise these findings into measures in the discussion section.

Discussion

This study investigates what students and supervisors of master's theses in chemical engineering find difficult and important when working with students' data commentaries, and also what pedagogical challenges are pertinent to data commentaries. The study aligns with

previous work on the teaching and learning of data commentaries (Poe, Lerner, and Craig 2010), and adds additional perspectives on data commentaries by looking primarily at student's and supervisor's perceptions of what happens or is supposed to happen in a data commentary rather than the textual aspects of the commentary (Sancho Guinda 2012; Stoller and Robinson 2013). The perceptions are important for understanding the teaching and learning context and for developing informed advice about important foci for the supervision of data commentary writing. We argue that such advice is of particular importance for students in disciplines in which data commentaries have a structuring role in the results section.

The results from the generic, semi-structured parts of the interviews show that the students and the supervisors bring up a wide range of themes as being difficult and important, which indicates that data commentary is not a topic that can be handled with a few simple guidelines. Many of the comments in this part of the interview concern selection of content and clarity. The students particularly seemed to struggle with what to comment on and how much to comment. The discourse-based parts of the interviews helped refine some of the themes mentioned in the semi-structured part. For instance, particularly the supervisor interviews stressed that the students did not express key points with necessary detail and focus and did not structure their commentaries in such a way that key results were appropriately highlighted.

In terms of understanding and responding to the challenges of detail and focus, there are different approaches. One of them is to see the challenges primarily as signs of the students being inexperienced researchers and scientific writers. This type of understanding was expressed by two supervisors, who emphasised that their students would probably develop a more precise writing style as they mature academically. The response may then be that students simply need more time and that they will eventually learn this if they pursue an academic career. Based on the findings of our study, however, we believe that there are at least a couple of dangers of such an approach. First of all, students' writing processes may become unnecessarily complicated if they are not familiarised with central aspects of writing in their discipline. Secondly, disciplinary writing is closely connected with disciplinary understanding, and imprecise writing may therefore be due to the lack of understanding of disciplinary content rather than limited writing experience or insufficient language proficiency. We therefore believe that the challenges students face in their data commentary should be highlighted to unpack disciplinary conventions and disciplinary understanding, following Bernstein's (1990) advice of applying a 'visible pedagogy' (see also Johns et al. (2006)).

In addition to challenges connected to detail and focus, the discourse-based interviews revealed that the teaching and learning of data commentary also involve challenges related to content learning and metalanguage. These findings give guidance to what type of support can be provided and how it can be organised. Specifically, we suggest three strategies to improve supervision of data commentary in the context investigated: developing a shared metalanguage, using a genre approach, and basing efforts on collaboration between content supervisors and academic writing experts. Working towards a shared metalanguage is a means to increase mutual understanding between supervisors and students. In our study, the problem of not having or not sharing a metalanguage is shown in the supervisors' frequent use of generic or metaphorical language to describe student texts, and in the difficulties that some students faced when trying to interpret these metaphors. The problem is

also indicated by the fact that the supervisors mean very different things when talking about what on the surface seems to be the same thing, for instance clarity.

The second measure, using a genre approach, has potential pedagogical value to master's thesis writing in general and to data commentaries specifically. A first indication of this is that we saw that the students had problems elaborating on the issue of 'clarity of explanation' in the pre-workshop interview (interview 1), but that their comments were more explicit in the post-workshop interviews (interview 3). We also believe that the structured and focused analyses of data commentary provided in the genre approach can be useful in supervision, even if such correlations cannot be established in this study but would require further research. In our discussion with the supervisors, we found that genre analyses were partly new to the supervisors, but that the discourse-based interviews made them see perspectives of or details in the texts that they had not thought about before. The pedagogical usefulness of a genre approach has also been demonstrated by Stoller and Robinson (2013) in their *Write like a chemist* project.

Regarding the third measure, basing pedagogical effort on collaboration between content supervisors and academic writing experts, our study gives clear examples of the potential contribution of content supervisors and writing experts in such a collaboration. The writing expert can support in the identification of functions of the genre via genre conventions and negotiate useful metalanguage with supervisors. Supervisors have the necessary content knowledge to make sure that the discipline-specific challenges are not missed, which may easily happen in stand-alone, general academic writing courses. Here, we particularly saw one example of a data commentary that looked perfectly acceptable from the perspective of language, structure and genre conventions but which included misunderstandings of vital disciplinary knowledge. This misunderstanding was not discovered until a carefully scaffolded reading of the data commentary was made in collaboration between the writing and the content experts. The collaboration therefore has potential to unpack aspects of writing and learning and make them accessible to students in ways which they would not have been unpacked if the writing and content experts had worked independently (Jacobs 2010). In addition, the collaboration can offer a space in which participants can share supervisory experience and develop supervisory practices. Harwood and Petrić (2017, 197) stress the importance of signalling the importance of supervision within a department to avoid the practice merely becoming an act of fulfilling prescriptive duties.

The forms of a content supervisor and writing expert collaboration need to be adapted to meet local conditions and resources available. It may for example take the form of faculty training as described by Anson et al. (2012) or involve joint contributions from content supervisors and writing experts through collaborative interaction or collaborative teaching, as discussed for instance by Jacobs (2007) and Gustafsson and Jacobs (2013). Another approach that has proven to be effective for both students and faculty is the use of assessment protocols to train students in how to engage in scientific review processes (Dowd et al. 2015; Reynolds and Thompson 2011).

Finally, although our results are not immediately generalisable or transferable to other contexts, we see clear overlaps between our observations and similar types of studies. For example, Poe, Lerner, and Craig (2010), in a different context (L1, undergraduate), argue that not enough attention is given to the selection of content in writing pedagogy and several studies discuss the difficulty for content specialists to unpack or articulate aspects of disciplinary discourse, which makes it difficult for students to learn these aspects (Geisler 1994;

Jacobs 2007; Pelger and Sigrell 2016). We therefore believe that our findings are relevant for other scholars working in highly specialised, disciplinary contexts. We particularly hope that our study can promote more studies that approach disciplinary writing both from the perspective of rhetorical functions in disciplinary language as well as how writing development is connected to disciplinary ways of thinking.

Notes

1. Two students who attended the workshops could not participate in the third interview and were therefore not included in this study (see the section *Interview procedures*).
2. The extracts from interviews in the paper are generally verbatim transcriptions but false starts and hesitations such as 'erm' have been removed in order to increase readability. For the same reason, fillers like 'mm' and 'yeah' from the interviewer have been deleted in a few of the extracts. Pauses are indicated by '….'.

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Appendix A. Interview questions used in student interview 1

General questions

1. Can you briefly describe your master's thesis topic?
2. What do you think is important when commenting on figures that report on results in master's theses in your field of study?
3. What might be difficult about commenting on figures?

Discourse-based part

4. Why did you choose this figure and text today?
5. What did you think about when you wrote the text?
6. Who do you consider to be your reader (in the master's thesis)?
7. What do you think the person you consider to be your reader sees in the figure you brought with you today; and what do you think he or she needs to know to understand the figure?

Appendix B. Interview questions used in student interview 2

General questions

1. What do you think is important when commenting on data in figures that report on results in your field of study?
2. Have you worked on the result part of your thesis since we last met?
3. Have you worked with result-reporting visuals (figures and tables) in the result part? What did you try to think about when you commented on the visuals?
   Follow-up question: Have you approached the commenting in the same way for all figures?
4. Was something difficult when you commented on your figures?

Discourse-based part

5. Why did you choose this figure and text today?
6. What did you think about when you wrote the text?
7. Who did you consider to be your reader?
8. What do you think the person you considered to be your reader sees; and what do you think he or she needs to know?

Appendix C. Interview questions used in supervisor interviews

General questions

1. What do you think is important when commenting on data in figures that report on results in your field of study?
   Follow-up: Is there a difference between research articles and master's theses in this respect?
2. What might be difficult about commenting on figures?
   Follow up: For you? For students?

Discourse-based part

3. In this figure (which is taken from your student's master's thesis): What do you see (and what might a master student see?), and what do you think is necessary to know?
4. Do you think that the text that accompanies this figure works?
   Follow up: Why/Why not?
5. Would you like to see some changes? If so, what type of changes would you like to see?
   Follow up/specification: Should anything be taken out or added to the commentary? Would you like to see something phrased differently?