Reporting Writing Process Feedback in the Classroom
Using Keystroke Logging Data to Reflect on Writing Processes

Nina Vandermeulen, Mariëlle Leijten & Luuk Van Waes

University of Antwerp | Belgium

Abstract: Keystroke loggers facilitate researchers to collect fine-grained process data and offer support in analyzing these data. Keystroke logging has become popular in writing research, and study by study we are now paving the path to a better understanding of writing process data. However, few researchers have concentrated on how to bring keystroke logging to the classroom. Not because they are not convinced that writing development could benefit from a more process-oriented pedagogy, but because 'translating' complex and large data sets to an educational context is challenging. Therefore, we have developed a new function in Inputlog, specifically aiming to facilitate writing tutors in providing process feedback to their students. Based on an XML- logfile, the so-called 'report' function automatically generates a pdf-file addressing different perspectives of the writing process: pausing, revision, source use, and fluency. These perspectives are reported either quantitatively or visually. Brief introductory texts explain the information presented. Inputlog provides a default feedback report, but users can also customize the report. This paper describes the process report and demonstrates the use of it in an intervention. We also present some additional pedagogical scenarios to actively use this type of feedback in writing classes.

Keywords: process feedback, writing processes, keystroke logging, self-assessment, writing from sources

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Contact: Nina Vandermeulen, University of Antwerp, Prinsstraat 13, Antwerpen, 2000 | Belgium – nina.vandermeulen@uantwerpen.be.

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1. Introduction

In writing research, keystroke logging has become an established method to observe writing processes (Lindgren & Sullivan, 2019). However, in writing instruction, the method is currently still scarcely used as a way to engage students in a data-informed reflection on their writing processes. In practice, teachers usually give feedback on the writing product. However, given that it is the writing process that generates the product, and previous studies have shown that the writing process influences the quality of the written text (see, for instance, Baaijen & Galbraith, 2018; Baaijen, Galbraith, & de Glopper, 2014; Breetvelt, van den Bergh, & Rijlaarsdam, 1994; Leijten, Bernolet, Schrijver, & Van Waes, 2019; Sinharay, Zhang, & Deane, 2019), we contend that feedback on the writing process should be taken into account as well. Especially also because process feedback explicitly stimulates self-reflection and self-regulation, allowing for generalization across tasks.

In this paper, we present the Inputlog process report tool. This tool is a newly developed feature that is integrated into the keystroke logging program Inputlog (Leijten & Van Waes, 2013). This feature has the potential to facilitate the use of keystroke logging in the classroom and to provide process-oriented feedback to students. The aim of this paper is two-fold:

1. Describe the process report function in Inputlog, and
2. Illustrate how it can be used in the writing classroom.

To better contextualize the process report we present in this paper, we briefly present the theoretical framework we used to design this tool. First, we situate the process report in a pedagogical context: why should process-oriented feedback be incorporated into the classroom? Secondly, we describe the methodological context. As the process report is a feature of the keystroke logging program Inputlog, we give a brief overview of the literature that relates to the use of keystroke logging to observe the writing process. The third part of this paper describes the process report tool itself. We outline the structure, content, and use of the Inputlog process report. Fourthly, an intervention study is briefly reported. In this study, upper-secondary students received feedback on their writing process, based on a customized process report. We describe the design of the process feedback and the procedure, together with its effect of the students' performance. This intervention study serves as an illustration on how the process report can be implemented into the classroom.

2. Process-oriented feedback in the writing classroom

In current education, the focus is no longer only on assessing students' performance. Emphasizing formative learning, classroom practice puts attention to the students' learning process. In this context, feedback plays an important role as it supports students in helping them take control over their learning (Nicol & MacFarlane-Dick, 2006).

The models of effective feedback as proposed by Sadler (1989) and Hattie and Timperley (2007) highlight three aspects to categorize feedback: (1) goals (which goals are targeted?), (2) level (what is the student's current performance level?), and (3) progress (which actions are needed to close the gap between the student's current level and the targeted goal?). Feedback can thus be defined as information about how the student's present performance relates to the goals of the task and the performance standards (Nicol & MacFarlane-Dick, 2006). The main aim of feedback is to enable students to reduce the gap between the current and the targeted performance level. To do so, students must first be able to monitor their learning during actual production (Sadler, 1989). This implies that feedback should be targeted at promoting self-regulated learning (Graham & Harris, 2018). In other words, by empowering students to understand the learning goal, judge their learning process, and choose strategies, feedback supports students to bridge the gap between the current and desired levels.

In the writing class context, feedback is usually given about the writing product. Students get feedback on, for example, (a selection of) text quality criteria. Sometimes, the feedback also targets the writing process. However, in those instances, it is often the case that the feedback is still indirectly focused on certain text criteria. For example, comments like "You should plan before you write because your text fails to incorporate all main ideas", addresses the planning during the process, but via an aspect inferred from the writing product, namely the lack of sufficient information. Though not (yet) common, there are several reasons as why to incorporate process-oriented feedback in the writing classroom.

First, previous research on feedback, in general, indicates the possibilities of process feedback, especially for complex learning activities demanding deep processing and problem-solving. Hattie and Timperley (2007) identified four levels of feedback: (1) task, (2) process, (3) self-regulation and (4) self. Though recognizing the value of feedback at the task level, they pointed out that feedback at the process level and self-regulation level was the most powerful when it comes to deep processing. These findings were confirmed by Paulson Gjerde, Padgett, and Skinner (2017) in a study on problem-solving cases. They found that process-oriented feedback had a more positive impact on the students' performance compared to outcome-related feedback. Moreover, the process-oriented feedback was also perceived as useful by the students.

Secondly, as we discussed above, the main aim of feedback is to close the gap between the current and targeted performance levels. Given that the writing product is the result of actions during the writing process (Van den Bergh, Rijlaarsdam, & Van Steendam, 2016), students might consider adapting their writing process if they want to move closer to the goal. In addition, by focusing on the process, the feedback looks beyond the specific assignment and increases the potential to transfer the acquired skills to future tasks (Butler & Winne, 1995; Schunk & Swartz, 1993; Walker, 2009).

Moreover, as Hayes and Flower (1980) observed, "a great part of skill in writing is the ability to monitor and direct one's own composing processes". Self-regulation plays an important role in this. Students need support to develop their self-regulating skills; they need to learn to monitor, direct and regulate their actions (Graham & Harris, 2018; Hattie & Timperley, 2007; Nicol & MacFarlane-Dick, 2006; Sadler, 1989). In other words, they have to regulate their writing process. By targeting cognitive processing, students are encouraged to select and adapt tactics and strategies according to the learning goals (Butler & Winne, 1995). Merely providing students with feedback on their level and the desired level is not sufficient; students should be actively involved in the feedback (Bandura, 2016; Carless & Boud, 2018; Nicol, Thomson, & Breslin, 2014). Positive results are obtained by several empirically-based tools that provide automated and individual feedback to support students during the writing process. Tools such as AcaWriter (Knight et al., 2020), Computer-Supported Argumentative Writer (Benetos & Bétrancourt, 2020), and Research Writing Tutor (Cotos et al., 2020) contain scaffolding features that trigger students' self-regulation when writing or revising their text.

A fourth reason is related to technological evolution. Until recently it was quite complex to observe and collect writing process data. However, thanks to the development of keystroke logging applications in the domain of writing (e.g., Scriptlog, Inputlog, Translog or CyWrite as described in Lindgren and Sullivan, 2019) it is now possible to capture the students' writing process in naturalistic settings and in an unobtrusive way.

3. Capturing the writing process with keystroke logging

3.1 Keystroke logging in writing research

To understand the nature of writing, researchers have used - and developed - a considerable variety of research methods (Mackey & Gass, 2015). In recent years, observing writers via keystroke logging has become more and more popular and the possibilities to analyze the resulting logging data have increased rapidly (Lindgren & Sullivan, 2019). Keystroke logging consists of a logging program that is activated on a computer, allowing the researcher to record every keystroke and mouse click or movement related to text production. These logging data are time-

coded, allowing researchers to reconstruct and analyze the writing process dynamics as a function of time and cognitive effort (Leijten & Van Waes, 2013). For more information on keystroke logging in general, we refer to Sullivan and Lindgren (2006), and Lindgren and Sullivan (2019).

In contrast to other methods that, for instance, mainly address aspects of the writing product (e.g., text quality or text complexity), the writer herself (e.g., self-efficacy) or the social context (e.g., collaboration or feedback), keystroke logging mainly focusses on characterizing the (cognitive) writing process (Graham, 2018). Although we realize that cognitive processes can only be inferred indirectly from process data, we contend that studying the dynamics of the writing process using keystroke logging data leads to insights in writing and a better understanding of the complexity of writing dynamics, complementary to other research methods.

Numerous studies focused on the interplay between text quality and writing processes observed with keystroke logging. Certain (combinations) of actions taking place during the writing process have a positive or negative influence on the quality of the text. Various influences of process characteristics like revision behavior (Barkaoui, 2016; Khuder & Harwood, 2015; Schrijver, Van Vaerenbergh, Leijten, & Van Waes, 2016), pausing patterns and writing fluency (Guo, Deane, van Rijn, Zhang, & Bennett, 2018; Medimorec, Young, & Risko, 2017), or process approaches like constructing an outline (Baaijen et al., 2014; De Smet, Brand-Gruwel, Leijten, & Kirschner, 2014; López, Torrance, & Fidalgo, 2019) are related to text quality. Other researchers focused on keystroke logging research and writing assessment (Bejar, Mislevy, & Zhang, 2016; Deane & Zhang, 2015; Sinharay et al., 2019; Zhang & Deane, 2015). These studies provided insights into the possible relations between writing process characteristics and text quality in the mother tongue, and second and foreign language studies (Tillema, 2012) and pupils or students with and without special needs (Beers, Mickail, Abbott, & Berninger, 2017; Berger & Lewandowski, 2013). In the current study, we build on these results and opted to use keystroke logging and/or process feedback in a classroom setting.

3.2 Keystroke logging in education

Keystroke logging has mostly been used as a research technique to collect data on, for instance, how to better understand the complex dynamics of writing processes and to improve writing education. However, until now, keystroke logging is scarcely used in the classroom. There are probably a few reasons why keystroke logging is hardly used in pedagogical settings.

One reason is the technical complexity of the logging tools and the logged data. Since keystroke logging is developed as a research tool, the output is quite technical, very fine-grained and often hard to grasp for laymen.

Another reason is that certain techniques, after being tested in a study, have not been made available for educational purposes. E.g., the tool JEdit, as used by

Lindgren and Sullivan (2003) and Lindgren (2004), has ceased to exist. In these studies, students were asked to formulate peer feedback for each other based on the replay of the writing process via JEdit. Luckily, in a later stage, the underlying techniques of the S-notation and the replay function have been incorporated in other keystroke loggers.

A third issue that complicates the adoption of keystroke logging in the classroom has to do with ethical principles (Conijn, 2020). Given that keystroke loggers register all the typing actions, they might register personal information such as passwords or chat conversations. Writing tutors should thus always inform students on this invasive element. Moreover, in some contexts it is advisable, for instance, to activate a special option provided in Inputlog that restricts the logging of characters to the main document only. When activated, the program does not store typing in other environments like mail or web browsers so as to exclude password entries and other privacy related information). Keystroke logging data are personal data, so according to GDPR, they must be safely stored. It is, therefore, advisable that schools that work with keystroke logging make transparent agreements about privacy issues and data processing.

Also, the 'time aspect' complicates the practical use of keystroke logging in education. A recent and innovative pilot study by Ranalli, Feng, and Chukharev-Hudilainen (2018) made use of both keystroke logging and eye-tracking in an educational setting. Chinese students wrote argumentative essays in English in a computer lab that was equipped with eye-tracking laptops. The keystrokes of the writing processes were logged with newly developed web-based software CyWrite (Chukharev-Hudilainen, 2019; Chukharev-Hudilainen, Saricaoglu, Torrance, & Feng, 2019). After each task, the participants had an individual feedback session of more than one hour with their tutor. They discussed both the text and the process data. The sessions were very much guided by the tutor. The approach of Ranalli and colleagues is very sophisticated, but also highly time-consuming for educational purposes (as they also state in their discussion). Not many teachers will have the possibility to see their students individually in an hour-long session. Therefore, it is important that research studies try to address the feasibility of interventions in a regular classroom context.

This is what we have done in the current study. We tried to facilitate the use of keystroke logging in writing instruction by bringing concrete information on the students' writing process into the classroom. Moreover, we focus on a process-oriented approach that is applicable in larger student groups, and that triggers the students to reflect on aspects of their writing process.

4. Report function in Inputlog

Inputlog is a keystroke logging tool to observe writing processes unobtrusively (Leijten & Van Waes, 2013). Basically, Inputlog logs various types of text input such

as keyboard actions, mouse movements, and program switches. The program can also be used to analyze the log files. At the moment, fourteen analyses are available each offering a different perspective (e.g. pausing, revision, source use, fluency). The analysis component contains descriptive analyses, sub-process analyses based on algorithms, and process visualizations. For more information on Inputlog, we refer to the program's website www.inputlog.net (and the manual that is available at the download page).

'Translating' complex and large data sets to an educational context is still a big challenge. Therefore, we have developed a new function in Inputlog called 'process report', specifically aiming to facilitate writing tutors in providing process feedback to their students in a simple way. Based on an XML-logfile, the report function automatically generates a pdf-file that brings together elements of the various analyses in one document. This allows tutors to address different perspectives of the students' writing process - like pausing, revision, source use, and fluency - in a single document[1].

The report function tackles some of the problems concerning implementing keystroke logging in the classroom that were discussed in Section 3.2. No technical background in keystroke logging analyses is needed to generate nor understand the report. Moreover, since the report function makes it unnecessary to analyze the raw data and only displays the information of a number of pre-selected variables at an aggregated level, no private or sensitive information is exposed. Thirdly, generating the report does not take much time and it can be used in the classroom in different ways depending on the time available (see section 5).

4.1 Default process report

Inputlog offers a so-called default process report that combines a carefully selected set of process perspectives describing the writing process in a user-friendly feedback text. The default process report is generated as a pdf-file that consists of several sections or building blocks (see Appendix A).

4.1.1 Global structure of the default report

The report is characterized by a strict hierarchical structure that allows students to easily orient themselves and quickly access the information they are looking for. The layout of the report is formatted according to the guidelines developed in the Information Mapping® method (see: www.informationmapping.com). All the information is split up in brief sections addressing a specific perspective to the process description.

The default version of the user report opens with two introductory sections: first, an intro in which the student is personally informed about the objectives of the text and secondly, an overview of themes dealt with. In the following sections, multiple writing process aspects are addressed. Every section starts with a brief

explanation of the process perspective at hand, also introducing the meaning of the variables that are reported or a brief explanation about the graph that is shown.

4.1.2 Content of the default report

As Inputlog generates more than a thousand variables, one of the main challenges in developing this report template was the selection of variables. The current selection in the default report is mainly based on a set of studies in which we explored different aspects of writing dynamics (Baaijen et al., 2014; Leijten, Bernolet, et al., 2019; Van Waes & Leijten, 2015). To reduce and group the variables, we used correlation analyses, principal component analyses (PCA), confirmatory factor analysis (CFA) and structural equation modelling (SEM). These analyses allowed us to select a representative set of variables that could be included in the default report. However, in the design of the report, we also opted for a flexible and user-centered approach, both from the tutor's point of view and from the students' perspective. For instance, the technical format allows the tutor to compose either a slightly adapted report (e.g., rephrasing or translating the explanatory text or reducing the number of sections) or construct a completely new report template suited to her - and the students' - needs.

The current default report contains information addressing the following perspectives:

- *Time characteristics*: information is provided on the writing process duration, and the way students divided their process between active writing and pausing; also a typing/thinking ratio is reported (Van Waes & Leijten, 2015).
- *Process description*: information is provided on the amount of text in the final text with the amount of text produced (and copied) during text production; also, the amount of characters per minute based on the product and process data is calculated.
- *Pausing behavior*: information is provided on the pausing behavior as this tells the students more about the cognitive efforts they experienced during writing (Wengelin, 2006); we report number of pauses (above the 200 ms threshold), and average duration of pauses, pause burst length and duration (above the 2000 ms threshold; for more background information on pause thresholds: see Van Waes, Leijten, Lindgren and Wengelin (2015)). Additionally a box-plot graph is plotted showing the student's pausing behavior at the within word, between word and between sentences level (Leijten, Van Horenbeeck, & Van Waes, 2019; Van Waes, Leijten, Mariën, & Engelborghs, 2017).
- *Revision behavior*: information is provided that shows the extent to which text has been deleted and inserted; we report the total number of revisions, the

mean number per 100 words and per minute and the mean length of a revision burst.

- *Source use*: information is provided on the time spent in the various (digital) sources consulted, relative to time in the main document; also the source use at the beginning, the middle and the end of the process is reported (Leijten, Van Waes, Schriver, & Hayes, 2014).
- *Typing characteristics*: information is provided on the lowest level to characterize their typing skill; we report characters per minute and the mean interkey interval during fluent text production.
- *Process and Fluency graphs*: two extra graphs are presented visualizing respectively the dynamics of the writing process (emerging text, document length, cursor position, pausing behavior and source use) and the variability in writing fluency during the writing process. The graphs are preceded by a brief instruction on how to read and interpret these graphs (see Appendix A).

4.2 Building a custom-made report template

The pdf process report is based on an XML template that allows tutors to create their own template from scratch, or to adapt an existing template. The template is built using a combination of two hierarchical structures (see Appendix B). Each section uses one of the structures. The first structure can be used to add textual information blocks, for instance, to write a welcome block, or to introduce the list of perspectives the project contains.

Figure 1 shows an example of such an information block and its underlying code.

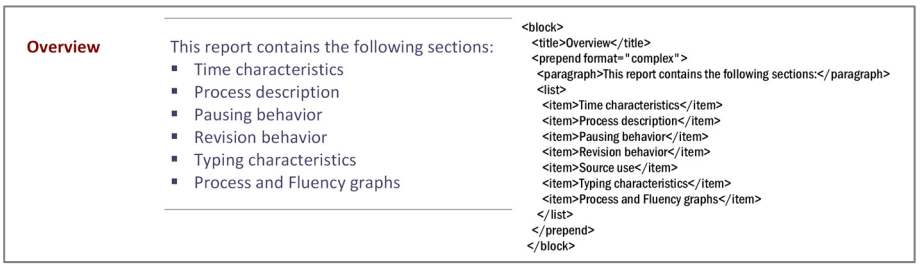


Figure 1: Example: Second block of the default template (Overview section). Showing both final report (left) and underlying XML-code (right).

The second structure is used to write sections in which specific process variables are reported. As a report composer, you can also add explanatory text before and after the variable names and values to make the technical information more

accessible to the targeted readers. An example of a block containing variable-related information and the underlying code of this block is shown in Figure 2.

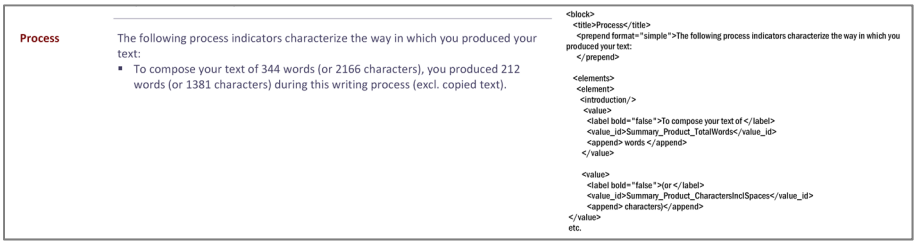


Figure 2: Example: Fragment of the fourth block of the default template (Process section). Showing both the final report and the underlying XML-code.

To include the variables <value_id> in the process report template, a list has been made available on the Inputlog website (see: www.inputlog.net/downloads). This list contains all the selected variables and a brief description of each of the labels. It can be used to customize the process report and include variables in a new template that better address the user's needs. At the moment this list consists of about one hundred variables taken from the current Inputlog analyses.

4.3 Generating a process report

The process report is always based on a specific log file or a collection of logging files. These log files can be used to give insight into the writing process of an individual student or to compare an individual student to a group or to benchmark data of related writing process research. Figure 3 provides an overview of the characteristics of each of the approaches presented.

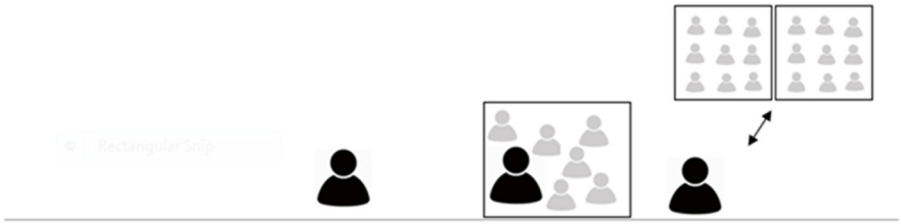
The easiest procedure is a simple two-step process in which students receive a single individual report. In that case, the procedure is limited to (1) collecting the logfiles (by recording the writing session), and (2) generating the process reports in the analysis component. This procedure can be carried out by the students themselves, or the tutor can generate the reports in a batch for the whole class.

However, as Figure 3 illustrates, there are more elaborate pedagogical contexts in which the report can be used. Therefore, we opt to describe the most elaborate procedure to generate a process report:

1. **Record writing sessio**n: Students start a logging session (either in Inputlog or Scriptlog); at the end of the session their document is stored, together with an XML-logging file containing a chronological list of all the events that were needed to compose the text at hand (all keystrokes, mouse actions, and external sources consulted). All these events are time-coded (ms).

2. **Analyze Inputlog data**: Tutors (or researchers) who would like to give insight into the writing process of an individual student in relation to the group (classes) or benchmark data have to analyze the Inputlog data first in order to calculate means that they would like to include in the report. In that case it is possible, for instance, to include phrases in the report like: "Your total process time [hh:mm:ss]: 00:17:03 (mean of group 00:25:12)".
3. **Generate (default/custom) process report**: In the Inputlog analysis tab, the tutor (or researcher) selects the report function and activates the template for the default process report or uploads a customized template. After loading the template, a dialogue box opens that allows changing some settings, like for instance the threshold used or the number of fluency intervals to include in the graph. Next, a user report (pdf-file) will be created for the selected logfile. It is also possible to select multiple logfiles at once to process the reports in batch or bulk mode. This will result in a collection of pdf-files that can be distributed.

Additional material such as a short video on how to generate a process report in Inputlog is available on the Inputlog website (https://www.inputlog.net/education/).



	Individual	Group	Benchmark
Comparison of writing process	No	To group results	To benchmark data
Create new template	No (use default)	Yes	No / Yes
Analyze Inputlog data	No	Yes	No / Yes
Availability feedback report	Immediately	Delayed	Immediately / Delayed
Involvement in creating feedback report	Student	Tutor / Student	(Researcher) / (Tutor) / Student

Figure 3: Comparison of three contexts in which the process report can be used.

5. Using process reports in the writing class

The process report function of Inputlog can be considered to be a kind of toolbox. It offers teachers the tools to implement process feedback in the classroom, and it offers students the tools to improve their writing. However, it should be stressed that the (isolated) process report on its own cannot be considered as effective feedback. To be a potentially effective feedback tool, it should be incorporated into a feedback flow in which the important feedback aspects as discussed in Section 2 are present. The report in itself offers the students clear and objective information

on their performance. Starting from that, students should reflect on their own writing. Trying to understand and thus reflecting on one's writing is the first step to self-regulate one's own learning. Moreover, the process report should be implemented in such a way that students are incited to take the actions needed to close the gap between their current level and the goal. Therefore, we suggest a basic pedagogical flow to employ the process report's feedback potential.

The process reports can be used in a wide variety of pedagogical flows. Figure 4 presents a basic example of how to integrate a process report in the writing class and stimulate students' self-reflection on their writing process.

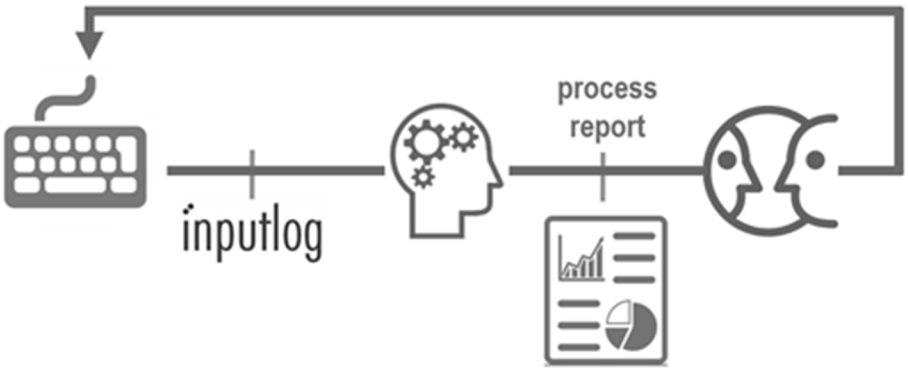


Figure 4: Example of a basic pedagogical flow to use process reports for self-reflection and peer discussion.

The basic procedure focuses on a student's individual reflection, combined with a peer discussion. The first step in this basic procedure is that students write a text while logging their writing process.

Text composition is followed by an individual reflection moment during which the students retrospectively answer a few questions concerning the way in which they organized their writing process (e.g., During which part of the process do you think you produced most text? Which proportion of your time do you think you spent on consulting digital resources?). The main aim of this self-reflection phase is to make the students actively reflect on their writing process from different perspectives.

In the next stage, the students receive their personal process report. They are stimulated to actively read the report and are prompted to compare their subjective findings from the previous stage with the reported data in the process report. Similarities and discrepancies feed the reflection. The result of this stage could be a short report in which they, for instance, briefly highlight five main observations that characterize their process.

This reflection is the input for a peer discussion during which they compare their reports with each other looking again for similarities and discrepancies. The effectivity of this kind of peer discussion is nicely demonstrated in earlier studies by, for instance, Lindgren et al. (2008) and Lindgren, Sullivan, Deutschmann, and Steinvall (2009). The process graph in the report could be a good starting point for the students to explain to each other how they organized their process.

Finally, students formulate explicit process goals they strive to achieve when composing a new text in a plan of action.

Taking students through this kind of flow, should enforce their process awareness and should provide them with concrete handles to reflect on and improve their writing process (awareness). In the research study below, we present a more elaborated variant on this procedure, including a benchmark comparison.

6. Application in a study

In this section, we briefly explain a study in which the Inputlog process report was used for feedback in a classroom setting. This study was part of a larger intervention. For a more detailed description of the complete study and the results, we refer to Vandermeulen, Van Steendam, and Rijlaarsdam (2020).

The part of the study reported here, serves as an illustration on how the report can be used in the classroom. Moreover, it addresses a first exploration of the report's effectiveness as a feedback tool.

6.1 Aim

We conducted an intervention study to explore the effect of process-oriented feedback on the synthesis writing of Dutch upper-secondary students.

6.2 Participants

A total of 33 Dutch students (18 male, 15 female) from grade 10 participated. The average age of the participants was 15.3 year (SD = .58). They belonged to three classes from one school. The participants completed the tasks in their own school. Written consent was obtained from all participants.

6.3 Data collection procedure

The participants wrote three informative synthesis texts at three different measurement occasions within one-week time. Their writing was logged and analyzed with Inputlog 7.0. The participants received process feedback at measurement occasions 2 and 3, prior to writing a new text. They logged in to our website and stepwise processed the feedback individually at their own pace, albeit within a fixed time limit of 30 minutes.

6.4 Materials

6.4.1 Writing tasks

A synthesis task is a source-based writing task. Participants had to integrate information from different sources into a new and independent text. The texts were evaluated by three trained raters by means of a rating scale with benchmark texts. The final scores consisted of the average of the three separate scores (reliability, Cronbach alpha = .73). The rating scale was based on a national baseline study with 332 participants and 1148 texts (Vandermeulen, De Maeyer, et al., 2020). In writing education, the use of benchmark texts that represent particular points on a text quality scale, is considered as a reliable and valid rating method (Blok, 1986; Bouwer, Koster, & Van den Bergh, 2018; Limpo & Alves, 2017; Rietdijk, Janssen, Van Weijen, Van den Bergh, & Rijlaarsdam, 2017).

6.4.2 Feedback

The feedback was based on the writing process report generated with Inputlog. The report was integrated into a feedback flow in which we encouraged students to reflect on their own writing process, and to compare their writing process to benchmark processes of better scoring students. In this way, we incorporated several principles of effective feedback into our intervention:

- Students were provided with concrete, understandable and objective information on their personal performance (Nicol & MacFarlane-Dick, 2006).
- Students were encouraged to reflect on their own writing to be able to self-regulate their learning (Graham & Harris, 2018).
- Students were provided with exemplars (i.e., the benchmark processes of better scoring students). Observational learning is a proven effective pedagogical tool for learning to write (Braaksma, Rijlaarsdam, & Van den Bergh, 2002; Fidalgo, Torrance, Rijlaarsdam, Van den Bergh, & Álvarez, 2015). Exemplars - within the students' zone of proximal development (Vygotsky, 1986) - provide students with constructive guidance and make them more engaged with the feedback; moreover, exemplars give an example of how the students can try to close the gap between their current performance and the objective (Handley & Williams, 2011; Hendry, Bromberger, & Armstrong, 2011). It creates an awareness of the process dimensions and produces a feedforward experience.

Adapted process report

As part of the feedback, the participants received the feedback report about their own writing process. For this intervention study, we translated and customized the default process report provided in Inputlog. More specifically, the report was

shortened and adapted to our target audience (grade 10 students) and the writing task at hand (synthesis text). This means that the process variables incorporated in the customized report had to be understandable for 16-year old students. Moreover, the selected process variables had to give information on process aspects related to the synthesis product.

We provided the participants with numerical data on 22 process variables and a process graph. The variable selection was based on previous studies (Aben, Van den Broek, Vandermeulen, Van Steendam, & Rijlaarsdam, 2017; Deane & Zhang, 2015; Leijten, Bernolet, et al., 2019; Van Waes & Leijten, 2015; Vandermeulen, De Maeyer, et al., 2020; Vandermeulen, Van Steendam, van den Broek, & Rijlaarsdam, 2020; Zhang & Deane, 2015). Moreover, taking into account findings of previous research on the importance of the timing of writing process activities (Breetvelt, Van den Bergh, & Rijlaarsdam, 1996; Knospe, Sullivan, Malmqvist, & Valfridsson, 2019; Leijten, Bernolet, et al., 2019; Medimorec et al., 2017; Van Waes & Leijten, 2015), the feedback included information on the distribution of certain writing activities over three intervals: beginning, middle and end of the writing process. We grouped the selected variables into four aspects characterizing the writing process of a synthesis text: (1) use of time (reading, thinking and writing time), (2) production and fluency, (3) revision, and (4) source use and source switches. To facilitate the interpretation, each writing aspect was briefly introduced. Besides these numerical data, the report also contained a process graph: a graphical representation of the writing process that integrates information on the several process aspects into one visual.

Benchmark processes

The participants were shown two benchmark writing processes: one process of a student scoring 1 SD higher, and another process of a student scoring 2 SD higher. The participants could compare their own writing process to these two exemplary processes. The examples consist of annotated process graphs: process graphs with detailed information on the four writing process aspects.

The benchmark process graphs were selected from the national baseline study (Vandermeulen, De Maeyer, et al., 2020) and linked to five text quality categories (-2 SD, -1 SD, average texts, +1 SD, + 2 SD). For each benchmark, four representative writing processes were selected (two for each of the two feedback moments), resulting in 20 exemplary process graphs. Though the processes led to a text with a similar text quality score, the writing process differed on a few aspects. In this way we tried to reflect the variety in the organization of writing processes.

Feedback flow

For this intervention study we embedded the Inputlog process report into a feedback flow. The feedback flow used in the intervention study is a more extensive application of the basic flow presented in Figure 4. Taking into account the basic

feedback elements, this intervention (1) provided the students with information on their current performance, (2) helped them to set goals, and to (3) identify actions to close the gap between current and desired level. The feedback was provided online1. The participants logged in to our website and processed the feedback individually at their own pace, albeit within a fixed time limit of 30 minutes.

First, participants received their text quality score together with a visualized scale with benchmarks (mean= 100, *SD*= 25). The students had to position their text on this scale (Figure 5). No other information on the quality of their texts was provided.

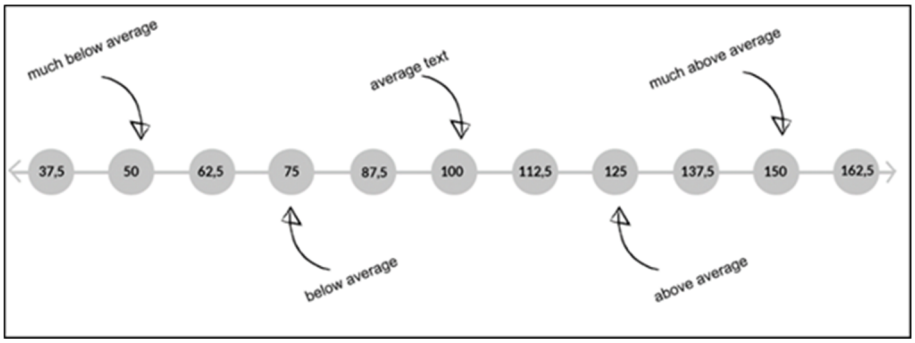


Figure 5: Text benchmark scale.

Next, participants were encouraged to reflect on the writing process of the text they wrote during the previous measurement occasion. They filled in a brief questionnaire aiming to stimulate the reflection on several process aspects (for example, When writing my text I found it difficult to figure out how I wanted to structure and build my text).

After reflecting on the four key writing process aspects (use of time, production and fluency, revision and source use), the participants received the actual information about their own process via the customized process report of Inputlog (cf. supra). The process report showed personal information on each of the four process aspects (for example, Figure 6), and contained visual information (i.e., the process graph).

The participants were also shown two benchmark writing processes of higher-scoring students. These exemplary processes were presented in an annotated process graph, including a source interaction bar (see Figure 7 for an example). This graph representation was comparable to the graph included in the participants' own reports.

Use of time	When writing a synthesis text, you have to divide your time over different subtasks. Part of your time you spend on writing (we call this: active writing time). The other part of the time you are not writing. You read the sources, you reread (part of) your own text or maybe you are thinking or just distracted. How did you divide your time (hh:mm:ss)? • total process time: 00:30:57 • of which active writing time: 00:19:28 • and of which thinking & reading time: 00:11:28 • So on average you spent 37.07% of your time on thinking or reading.

Figure 6: Example of information provided in the personal feedback report (translated from Dutch).

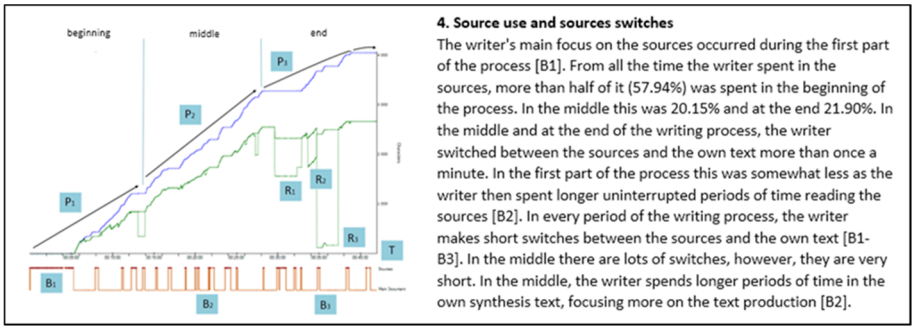


Figure 7: Example of annotated benchmark process graph (with information on the source use aspect).

Participants were encouraged to compare their own process to the two benchmark processes as this should help them to close the gap between their current level and a higher level. They received a handout with a general description of the four writing process aspects and had to fill in the blanks, thus constructing a detailed description of their own writing process in contrast to the descriptions of the benchmark processes.

Finally, the participants were asked to set goals for each of the four main writing process aspects.

6.5 Results: effect of the intervention

To measure the text quality scores at each of the observation occasions during the intervention, we used a text quality scale with 100 as the mean (SD = 25; see Feedback flow). We observed a gradual increase of the scores over time. Moment 1: M = 78.07 (SD = 16.10); Moment 2: M = 83.32 (SD = 14.06); Moment 3: M = 85.78 (SD = 12.82). Repeated measures analysis showed that the intervention had an overall significant effect on the quality of the written texts ($F(2,64) = 4.992$; $p = .010$). Pairwise comparisons showed that the mean score at measurement occasion 3 was 7.71

points higher than the mean score on measurement occasion 1. This difference in scores was significant (p = .004). So, after receiving feedback at two occasions in which they had to compare their own writing process to the process of better scoring students, the participants performed significantly better.

The intervention was compared to a representative sample of 1081 corresponding texts of students from three grades (grade 10-12) from the national baseline study (Vandermeulen, De Maeyer, et al., 2020). The participants in this sample wrote the same three synthesis texts, however without receiving any feedback. The baseline study can, therefore, be interpreted as a stable control condition. In the baseline study, we observed a development over the grades (F(2,1078) = 40.91; p < .001): grade 11 wrote significantly better texts than grade 10 (p < .001) and grade 12 wrote significantly better texts than grade 11 (p < .001). The effect size for the difference in text quality scores between grade 10 and grade 11 was .60.

The effect size for the intervention study was calculated by looking at the progress made between the first and second measurement moment, and between the first and third measurement moment. We observed a small effect after the first feedback (*ES*= .35) and a moderate effect after the second feedback (*ES*= .55).

When comparing the progress made by the grade 10 participants of the intervention study (*ES* = .55) to the progress made by the grade 10 participants in the control condition (*ES* = .60), we can conclude that the process feedback had an effect comparable to almost one grade of regular schooling.

7. Conclusion and discussion

There is quite some evidence that a focus on process aspects plays an important role in optimizing writing instruction (Hattie & Timperley, 2007; Paulson Gjerde et al., 2017). However, up till now, it was quite difficult for tutors to actually integrate this perspective in teaching practice. Especially the development of keystroke logging tools like CyWrite, Scriptlog, Translog, and Inputlog has changed this situation and has created new possibilities to address process related writing activities in pedagogical contexts. In this article we focused on a module in Inputlog that has been developed to enable writing tutors to report on the students' writing processes from different perspectives.

Keystroke logging based process reports can play an important role in students' writing development. By focusing on the process, instead of (only) on the outcome, it encourages students' self-regulation process (Graham & Harris, 2018; Hattie & Timperley, 2007; Nicol & MacFarlane-Dick, 2006). The process report generated by Inputlog gives the students insight into their own writing process. The program provides a user-friendly procedure to generate a default report giving information on several writing aspects (time characteristics, process description, pausing, revision, source use, typing characteristics, and process and fluency graphs).

Moreover, users can generate a custom-made report in which both the textual information blocks and the process variables can be customized depending on the class and task context. Providing students with information on their process is a first and important step for feedback as it has the potential to enable students to concretely reflect on their own performance, and starting from there, to close the gap between their current and desired performance (Carless & Boud, 2018; Nicol et al., 2014).

Though the process report provides the content for feedback, we stressed the importance of embedding it into a feedback flow that stimulates reflection and goal setting (Carless & Boud, 2018). Reflection can be stimulated by tutor questions or by a questionnaire as used in the reported intervention study. Moreover, by facilitating peer discussion in class, students compare their writing process to that of others based on variables derived from their recorded data. Looking for similarities and differences can help students in formulating goals as they are actively inspired and challenged to think about various writing approaches. Depending on the class setting, it is also possible to have students compare their process to the class mean, or to exemplars such as the benchmark processes we used in the reported intervention study. An advantage of this last option is that exemplars can be selected in such a way that they represent writing processes of better scoring students, thus clarifying what good performance could be and therefore providing strategies on how to close the gap between the students' current level and the goal.

In this article, we briefly reported on an intervention study carried out with 33 Dutch Grade 10 students. Participants received feedback at two measurement occasions within one week. For this intervention study, a custom-made process report was used, considering task and age group. In the feedback flow, reflection and comparison with benchmark writing processes were incorporated. The process-oriented feedback based on the Inputlog process report proved to be successful as the participants wrote significantly better texts after two feedback moments. The process-oriented feedback had an effect comparable to almost one grade of regular schooling.

We realize that motivation and novelty effects might have influenced the results of the intervention to a certain extent. Therefore, in future studies, we would like to report on more elaborate intervention studies in which the process perspectives are more carefully addressed in different stages of the learning process (Conijn, Cook, Van Zaanen, & Van Waes, 2020). It would also be interesting to add a follow-up test to the intervention study to examine whether the process-oriented feedback has a long-term effect. Moreover, by contrasting a process feedback approach to a more traditional product approach, we hope to be able to more explicitly address the specific strengths and weaknesses of the reports presented, also considering the complementarity of both approaches.

Another aspect that should be addressed more thoroughly in future studies, is the precise effect of the feedback. The intervention study we reported on clearly shows that process-oriented feedback based on Inputlog process reports resulted in better quality texts. So, the feedback had a positive effect on the students' performance. However, we do not know what exactly caused this improvement. Therefore, future studies should explore which elements of the feedback are effective. Is it the mere reflecting on one's own process, based on the data of the process report? Or is it the comparison with other processes? Another interesting angle would be to explore the effect of the feedback on the writing process itself. As the feedback targets the writing process, we would like to get insight into changes in this process provoked by the feedback. To formulate an answer to these questions, another study has to be set up in which we can control the influence of each of the several feedback components separately. Moreover, we need to control for task effects on the writing process, before being able to explore the difference in the writing process between pretest and posttest.

Though the research questions raised above require a different study, we already found some traces of feedback effect - other than the effect on text quality - in our data. As part of the intervention study we reported on, we gathered additional data via questionnaires that allow us to interpret the feedback effect. Exploration of the questionnaire data gave us some indications of the effective elements of the feedback and the effect of the feedback on the writing process. First, questionnaire data are available on how students evaluated and used the feedback of the intervention. We explored the correlations between the progress in text quality the students made and their feedback experience. We found that students who wrote better texts after the intervention reported that the feedback gave them more insight into their use of time ($r = .546$, $p = .004$) and use of sources ($r = .467$, $p = .025$). Moreover, they evaluated the comparison with benchmark texts positively ($r = .394$, $p = .038$). And while writing a new text, they considered the feedback concerning time use such as information on reading, thinking and writing time ($r = .467$, $p = .019$). Secondly, exploration of questionnaire data on participants' self-efficacy before and after the intervention, showed that they felt more confident after processing the feedback on a few aspects, such as dealing with the sources ($F(1,27) = 6.95$; $p = .014$) and structuring the text ($F(1,27) = 6.68$; $p = .015$).

At the technical level, we think it is necessary to gradually expand the number of available report variables. However, these additions require additions to the program library, and sometimes also further optimization of the basic logging itself (e.g., with respect to revision data which are not always fully reliable at the moment as the logging does not yet fully take into account all automatic operations that are initiated in the background by MS Word.) Also the possibility of creating more visual representations of central process characteristics should be explored as visualizations could help students in interpreting more complex data (Vieira,

Parsons, & Byrd, 2018). Moreover, apart from the technical aspects, also at the theoretical level, we need more research that leads to a better mapping of keystroke logging characteristics to the underlying cognitive writing processes (Conijn, Roeser, & Van Zaanen, 2019; Galbraith & Baaijen, 2019). Research that focuses on this kind of mapping should - among other elements - certainly also take into account the interdependency of keystroke features and the variability that relates to the distribution in time. Depending on the type and characteristics of the writing task (such as genre, goal, time on task ...) other variables might be required. For example, a task that involves rewriting a previous draft requires feedback on other variables than a task for which students got 20 minutes to write a final text.

Finally, we think in this stage it is also very important to further investigate tutors' specific needs with respect to the contents of the report, its structure, and its usability (Conijn, Van Waes, & Van Zaanen, 2020). For instance, we think that the possibility to automatically include class or group means in the process report would enrich the interpretation and use of these feedback reports. Moreover, a more user-friendly 'report builder' to create tailor-made reports is on our agenda as this tool could lower the threshold to specifically adapt the process feedback to the tutor's personal needs. Investing in the professional development of tutors will be crucial for the potential of the process report as a feedback tool. Training sessions should address practical issues (creating the report, addressing possible privacy issues), motivational issues (teachers' attitudes and beliefs (Ertmer, Ottenbreit-Leftwich, Sadik, Sendurur, & Sendurur, 2012)), and educational issues (embedding the process report into a feedback flow). This could also be a good incentive to share newly developed report templates with the (multilingual) global writing community, for instance via an open platform where tutors can also further discuss their approaches.

Note

[1] A translated example of a complete feedback flow can be consulted online via https://liftwritingresearch.wpcomstaging.com/process-oriented-feedback/

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Appendix A: Example of a default process report

inputlog

Process report: Nicky Peterson | 7/06/2016 - 10:09

Intro

Dear Nicky Peterson

This feedback report provides you with some process and product writing characteristics. Together they describe and typify your writing process of the composition task at hand.
This report will help you to reflect upon the way you completed this task. It is also useful to compare your writing process for different writing tasks, or as a basis to compare your writing strategies with those of your fellow students.

Mariëlle Leijten and Luuk Van Waes
Research group Professional Communication

Overview

This report contains the following sections:
- Time characteristics
- Process description
- Pausing behavior
- Revision behavior
- Source use
- Typing characteristics
- Process and Fluency graphs

Time

In general when composing this writing task you divided your time as follows:
- Total process time (hh:mm:ss): 00:17:03
- Total pausing time (taking into account a pause threshold of 2000 ms): 00:03:44
- Total active writing time (taking into account a pause threshold of 2000 ms): 00:13:19
- The ratio of the time you spent 'thinking' versus the time you spent 'typing' fluently (threshold 2000 ms): 21.94%

Process

The following process indicators characterize the way in which you produced your text:
- To compose your text of 344 words (or 2166 characters), you produced 212 words (or 1381 characters) during this writing process (excl. copied text).
- Characters per minute (product): 126.94
- Characters per minute (process): 80.94
- Proportion product/process: 132.17% [Note: the lower the percentage, the more revisions you made.]

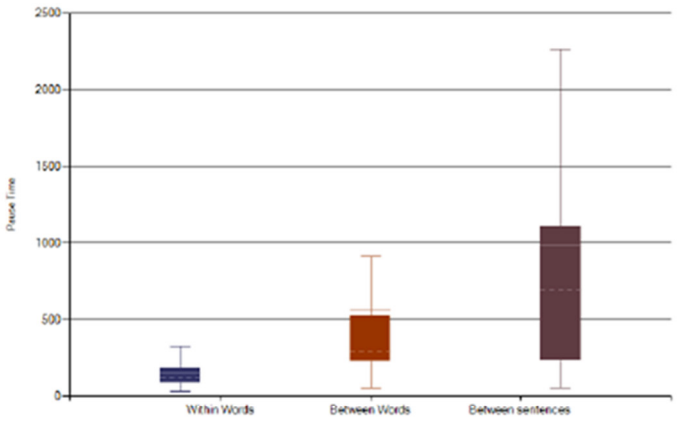
Pausing behavior

An analysis of your pausing behavior tells you more about the cognitive efforts that was needed to produce your text. The pauses in your text production are analyzed from different perspectives:

- Total number of pauses (larger than 200 ms): 603
- Average pause duration (larger than 200 ms): 463 ms
- Median Pause burst length: 17.50 characters (standard deviation: 43.99)
  [Note: A P-burst is defined as the writing activity between two pauses that exceed the defined pause threshold, i.c 2000 ms.]
- Median Pause burst duration: 13.62 seconds (standard deviation: 20.66)
  [Note: A P-burst is defined as the writing activity between two pauses that exceed the defined pause threshold, i.c 2000 ms.]

Pausing levels

The graph below shows a boxplot of your pausing behavior at the following text levels: within words, between words and between sentences (pause threshold > 30 ms):



Revision behavior

The analysis of your revision behavior shows the extent to which you deleted and inserted text while composing.

- Total number of revisions: 44 deletions | 38 insertions
- Mean number of revisions per 100 words: 37.61 per 100 words
- Mean number of revisions per minute: 4.81 revisions per min.
- Median length of Revision bursts: 20.00 | stdev. 8.63

Source use

The analysis of your source use documents the way in which you interacted with the (digital) sources you consulted while composing your text.

- On average you spent 51.87% % of your time reading sources.
- beginning of your process: 54.73%
- middle of your process: 17.60%
- end of your process: 27.67%

Typing characteristics

The analysis of your (motoric) typing behavior shows that:

- Your average typing speed is: 68 characters per minute. (stdev. 47.91).
- Your average interkey interval between two characters is: 273.63 ms (stdev. 51.44).

Process graph

The process graph (see appendix 1) shows a graphic representation of the dynamics that characterize your writing process.

- The blue top line represents the number of characters that were produced over time (x-axis). The steeper the line, the more text you produced (fluency).
- The green line represent the document length at every stage in the process. The further the green and the blue line diverge from each other, the more text was deleted.
- The green dotted line shows in which part of the text you were revising or inserting new text. It is an indicator of non-linearity. When the green dotted lines overlaps with the green line, you have been producing text at the point of utterance. When you get closer to the x-axis, it means that you are composing or revising text at the beginning of the document.
- The orange dots represent the location of the pauses that exceed the given pause threshold (i.c. 200 ms).
- Finally, The line graph at the bottom of the figure represents the interaction between your main document and the sources you consulted.

Process graph
See appendix 1

Fluency graph

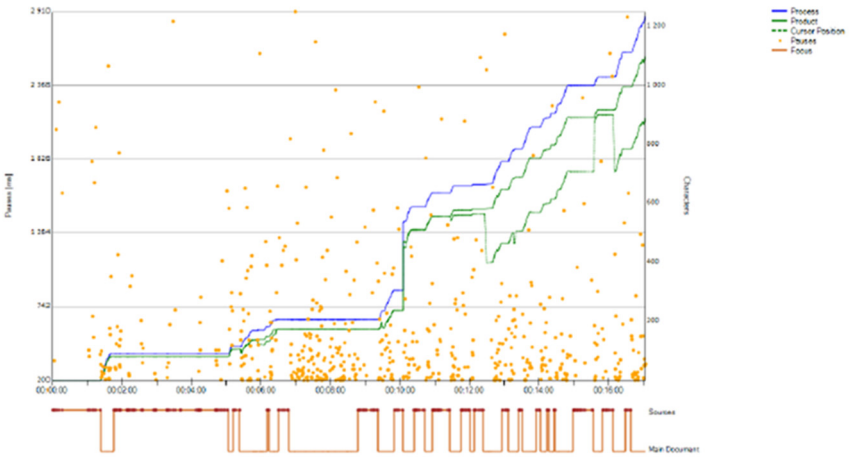
The fluency graph (see appendix 2) shows a graphic representation of the proportion of text that is produced in the different intervals of your writing process.

- Task variation: The green lines represents the proportion of characters that were produced per interval. The higher the text production in that interval, the closer the line will reach the 100% mark. The maximum score of 100% is attributed to that time zone in the task execution that is characterized by the most fluent text production (see green shaded vertical zone).
- Absolute variation: The blue line represents a comparable view to the variation in the text production. However, the maximum for this line is based on an absoulte measure that is defined at 400 cpm (corresponding to a highly fluent text production). This line enables you to easily compare your fluency variation to other writers or for different writing processes.
- Personal variation: The red line also represents your variation in text production, but in this case relative to your personal maximum fluency (either based on this specific task, or on the results of a copy task).

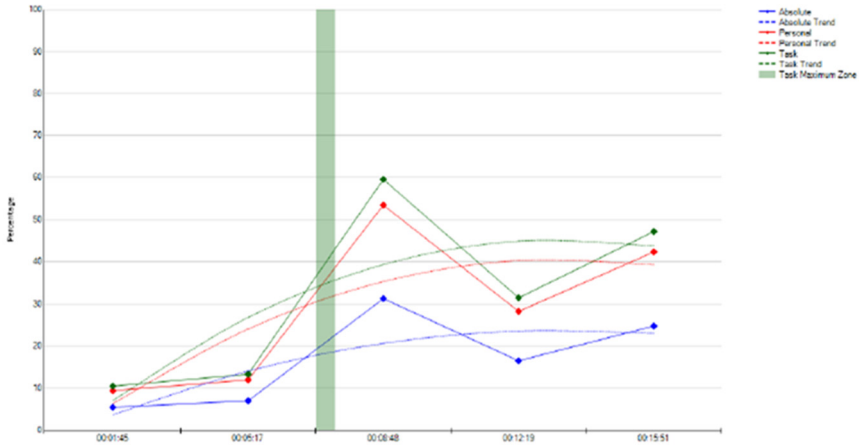
Fluency graph
See appendix 2

Although much care has been taken to ensure the accuracy, completeness and reliability of the information provided in this report, we make no representations or warranties of any kind, express or implied, about the completeness, accuracy, reliability or suitability.

Appendix 1: Process graph



Appendix 2: Fluency graph



Appendix B: Basic structures used in the XML-report template

Structure 1

Block

- title
  - prepend
    - paragraph
    - list
    - paragraph

Structure 2

Block

- title
  - prepend
    - elements
      - element
        - introduction
          - value
            - label
            - value_id
            - append
      - element etc.