Writing and Thinking: What Changes with Digital Technologies?

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Abstract The relationship between writing and thinking explicitly or implicitly runs through all the contributions to this book. There is no writing without thinking and there is no new writing technology that does not alter the way thinking in writing happens. Many layers of the relationship between thinking and writing await conceptualization. Four of them that seem most widely affected by the currently unfolding transformational processes are described in more detail in this chapter: (1) the connection of inscription and linearization to thinking; (2) the relation of sub-actions of the writing processes to thinking; (3) the influence of digital technology on connected thought, networked thinking, and collaborative writing; and (4) the challenges of higher-order support for writing, including automatic text generation for the conceptualization of the writing-thinking interplay. We close with a short statement on the necessity to adopt human-machine models to conceptualize thinking in writing.

Keywords Writing and thinking · Orality and literacy · Effects of digital technology on thinking

1 Introduction

Writing and thinking, particularly in academic contexts, are so closely related to each other (see, for instance, Langer & Applebee, 1987; Oatley & Djikic, 2008; Bereiter & Scardamalia, 1987) that Kellogg (2008) suggests we think of them as twins:

> Writing an extended text at an advanced level involves not just the language system. It poses significant challenges to our cognitive systems for memory and thinking as well. . . . Thinking is so closely linked to writing, at least in mature adults, that the two are practically twins.

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> Individuals who write well are seen as substantive thinkers, for example. (Kellogg, 2008, p. 2)

Writing depends on thinking skills, and is, in turn, an activity that trains and develops various intellectual abilities such as conceptual, systematic, or critical thinking. Writing and thinking depend on both cognitive and linguistic skills and, additionally, on the quality of their interaction. We assume that the human mind runs on language as much as it runs on cognition. Thinking needs the lexical symbols, the grammatical forms, and linguistic connectors to create thought units as well as it needs the cognitive operations to process the flow of thought.

In this contribution, we consider the effects of the latest generations of digital technology on the relationship between writing and thinking. We start from the idea that writing is a way of linearizing thought into a chain of words that ideally are organized cohesively and coherently to make their content comprehensible for readers. Writing technology, in all its previous and current variations, allows for a step-by-step crafting of language, thus offering more control over the production of thought than speech alone. In its developed forms, writing has been called a way of restructuring or transforming knowledge (Kellogs, 2008; Bereiter & Scardamelia, 1987). We will also discuss what digital technology offers for the transformation or restructuring of thought beyond traditional writing media.

2 Traditional Views

How exactly does writing support or influence thinking? This was a much-debated question, particularly in the 1980s and 1990s, to which no simple answer was and still is possible. In a thorough survey of research, which can serve as a starting point for our purpose, Applebee (1984) summarized the common assumptions of his time about what it is that writing adds to thinking:

- "The permanence of the written word, allowing the writer to rethink and revise over an extended period;
- the explicitness required in writing, if meaning is to remain constant beyond the context in which it was originally written;
- the resources provided by the conventional forms of discourse for organizing and thinking through new ideas or experiences and for explicating the relationships among them;
- the active nature of writing, providing a medium for exploring implications entailed within otherwise unexamined assumptions." (Applebee, 1984, p. 577)

At the time, these assumptions seemed intuitive and probably still are. They were, as Applebee showed, less grounded in research than in the general assumptions of literacy theory. In particular, the historical and anthropological comparisons of literate and illiterate societies (Goody, 1977; Levi-Strauss, 1962; Ong, 1982) had provided assumptions that were transferred to the field of writing. However, several

confounding variables mediate the relationship between writing and thinking development such as writing practices, schooling, and course design, which obscured a clear-cut causal influence of writing on thinking (see, for instance, Chandler, 1994; Finnegan, 1988; Street, 1984). Scribner and Coles' study of the Vai (1981), some of whom used a writing system but did not experience the additional effects of schooling, pushed against the conclusion of Ong and others that written literacy restructures thought. It is difficult to come to general assumptions of how the interconnection of both actually works and several levels or layers of theory building and research have to be distinguished:

Microprocesses of inscription and formulation: Language creation in writing happens in interaction with a writing tool that fixates words on a writing surface. It also mediates the inscription of sound to sight, thus making language visible. When writers see what they write, they can align the expressed thought with the thought they have in mind, or formulate the thought through the process of inscription (see Blau, 1983; Marcus & Blau, 1983 for accounts of what happens when writers cannot see what they are writing) today, such fine-grained processes of formulation are best studied by keystroke logging technologies that display the words inserted and changed in relation to the text development (Wengelin & Johansson, "Investigating Writing Processes with Keystroke Logging"). Most research comes from cognitive studies in the tradition of Hayes and Flower (1980), Hayes (1996), and Hayes (2012), but also from earlier psycholinguistic research on formulation and language production (see Levelt, 2013). At the micro-level, it is essential for an evaluation of thinking quality to understand how usable the technology is for the inscription of words, as this is related to the fluidity of the writing and thinking process (Kruse & Rapp, "Word Processing Software: The Rise of MS Word"; Kruse et al., "Finding the Right Words: Language Technologies to Support Formulation").

Writing processes and the sub-actions of text production: Writing demands many separate intellectual activities that traditionally add up to what is called text production. Most scholars today agree that writing is a recursive activity involving an ongoing reconsideration and revision of what has been written and successively improving the content, language, and structure of the text. Preparatory activities such as idea generation, source reading, summarising, structuring, and outlining may precede the more formulative activities of word choice and sentence construction. However, the extent to which writers engage in such prewriting activities has been the subject of debate. Early theories of "incubation" posited periods of unconscious rumination about an upcoming or ongoing text. Lauer (2004), pointing back to the work of Young et al. (1970), explains the process of inquiry "as beginning with an awareness and formulation of a felt difficulty followed by an exploration of that unknown, then proceeding through a period of subconscious incubation to illumination and verification" (p. 9). Further inquiry found that writers plan in a variety of ways, some with a general sense of exigency or purpose but with reliance on the emerging text to discover ideas, others with an explicit process of mapping out or outlining the structure and content of their writing (Baaijen et al., 2014; Isnard & Piolat, 1994). Prior to the development of digital planning tools, writers were urged to use various invention strategies before beginning to formulate their ideas into words.

Educationally, instructors incorporated activities into the writing process such as looping, tree diagramming, and listing. These invention heuristics were perhaps best exemplified in McLelland's textbook, *Writing Practice: A Rhetoric of the Writing Process* (1984), which included a chapter on invention with exercises such as brainstorming, cubing, starring, personifying, and creating metaphors. More sophisticated invention strategies based on linguistic tagmemics, such as the use of the particle/wave/field heuristic earlier developed by Young et al. (1970; also included in McLelland) became popular as a way for writers to brainstorm ideas. At their core, these strategies relied on categorizing or taxonomizing thought through a combination of linguistic and visual/diagrammatic representations or through questioning strategies (Larson, 1968), some of which drew on principles and methods from classical rhetoric (see Enos & Sypher, 1977; Young, 1976). The results were said to spark memory, extend thinking, reveal gaps in knowledge needing to be filled, and create structural outlines for whole texts (each category of information, for example, constituting a paragraph or section of text).

Writing as a way of student learning: When writers think about a topic or problem, writing may help them organize their thoughts and gain clarity about their intentions, arguments, and conclusions. Emig (1971, 1977) showed the similarities between writing and learning and noticed that revision of student papers leads to self-directed learning and thinking. Students carrying out writing or research projects use writing for documenting the information they have gathered and for connecting them to coherent papers or theses. Writing and thinking in such contexts are connected with literature searches, reading and reviewing literature, synthesizing knowledge, developing arguments, structuring a paper, and more. Here, writing is a way of learning about a topic by thinking it through. This kind of thinking by writing depends on the genres used and the assignments given (Anderson et al., 2015). It is also key to learning disciplinary epistemologies and thinking styles (see Devitt et al., "Writing and Learning: What Changed with Digitalization?").

Epistemological and intellectual development: Moving to a higher level of the organization of thinking abilities, the dimension of intellectual development comes into focus and the question arises as to how writing affects the growth of thinking abilities and of epistemological beliefs (see Baaijen et al., 2014). Here, the focus changes from the process or course level to one that tries to assess the overall thinking competencies and skills that result from writing. The connections of writing to the internet and web become salient as they position writers and thinkers differently than before with respect to the thoughts and writing of others. The relations of thinking to digital or computer literacy become relevant but also how digitalization influences critical thinking as Bean and Melzer (2021) conceptualize it.

The interactive and intertextual dimension: Writing is a seemingly isolated activity but by its nature it is also a thoroughly social activity, encouraging writers to use the thoughts accumulated in a discipline or in an activity field. Writing offers different kinds of interactions with other writers and their writings than oral communication does; intertextuality is an essential attribute of academic discourse where what is thought and written is related to what others have already said and where the origins of ideas have to be specified when recoverable or when they are common

knowledge or tacitly learned (see Bazerman, 2003). Thus, writing may be seen as enculturation into the thinking habits of a discipline or group of users. Bruffee (1999) pointed out that writing is one of the roots of collaboration both among students and within disciplinary knowledge groups. Feedback is seen as a necessary practice to foster writing development as well as text development.

Even if there is considerable overlap between these levels, they should be distinguished to arrive at consistent theories and valid research. Another theoretical development explored the highly contextualized nature of literate practice, suggesting that writing can have different effects on thinking at each of the five levels depending on a host of factors such as genre, purpose, rhetorical situation, disciplinarity, and the affective states of the writer.

An equally persistent problem as that of different levels of analysis arises from the vagueness of the term "thinking" and the lack of appropriate theories that avoid cognitive or linguistic reductionism. Thinking can neither be reduced to cognitive activity (no academic thinking without language), nor can it be made equal with inner speech (no thinking without cognitive activity). Also, thinking cannot be reduced to automatic routines that can be processed in a computational way, any more than it can be reduced to conscious processing of thought or logical reasoning, as Kahnemann (2012) has pointed out. To better understand thinking, Kahneman suggests that we consider both the automaticity of thinking subroutines and the linear, controlled, effortful, and conscious part of sequential thinking. Thinking relies on myriad automatic processes, both linguistic and cognitive in nature; but in academic writing we practice a more linear, step-by-step process of thinking that is needed for knowledge construction.

3 Current Transformations of Writing Induced by Technology

With the invention of the computer, the hope of improving thinking was expressed at an early stage of development (Bush, 1945; Engelbart, 1962; Licklider, 1960; Rheingold, 1985). The expectation that the computer would foster thinking has been one of the great promises of the digital age. This was not only proposed in the context of word processors but more so of the computer as a whole and its potential uses, even if word processors became a main application (Heilmann, "The Beginnings of Word Processing: A Historical Account"; Kruse & Rapp, "Word Processing Software: The Rise of MS Word") to align the computer with human thinking.

In digital writing, the computer is more than a passive inscription tool for letters and words as the typewriter and other media once were, but has become an interactive agent (see Baron, 2009). Word processors have become work benches for the creation of text, offering many tools for writers to apply. The tools guide the writers' thinking in various ways, not only by assisting with lower-order concerns like line feeds, grammar checking, hyphenation, and pagination but increasingly by taking care

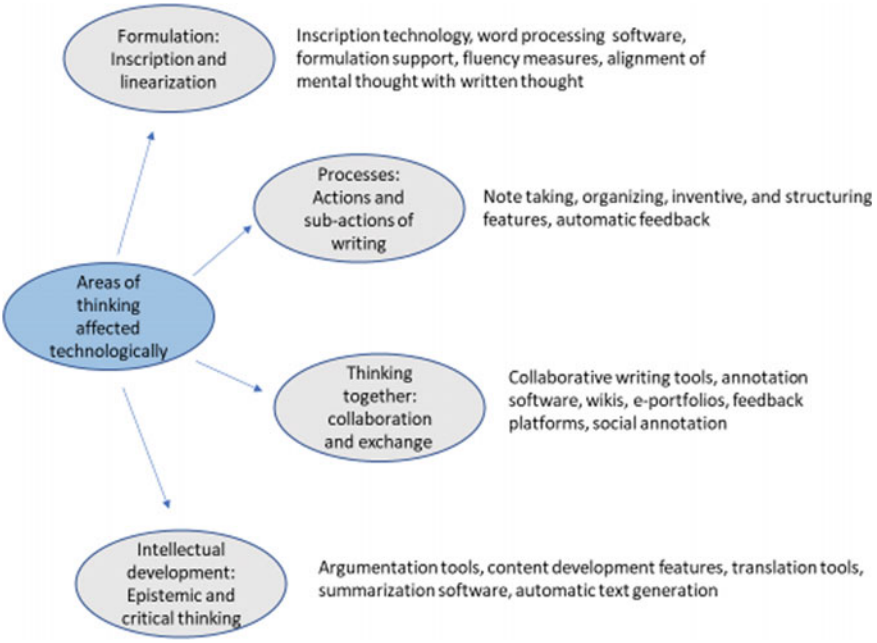

Fig. 1 Main areas of thinking influenced by writing technology

of higher-order thinking activities such as structuring, formulating, searching, and synthesizing. The influence of such technologies on human thinking cannot be seen only as a form of tool usage or of a supportive assistance of the computer but also in the way that they substantially change the demands on human thinking. We will suggest some hypotheses at the end of this contribution as to how this can be conceptualized.

Figure 1 provides an overview of four kinds of thinking we see supported by technology use and the kinds of technologies on which this support is based. We will consider each of them individually.

3.1 Thinking, Inscription, and Linearization

If writing and thinking are twins, as Kellogg (2008) has put it, then the question arises of what digital technology adds to a smooth and productive interaction between the two. Thinking and writing are, after all, substantially different processes; synchronizing them means adapting digital technology to the peculiarities of human thought production as it, conversely, means adapting writers' thought processing to the word processors' working principles. That is, there is no linear influence of technology on thinking because of the recursive nature of writing and because users must adapt to

the tools. In turn, the tool developers have to keep the users' minds in view it they want to optimize usability.

The most basic function of writing technology is to provide a way for the inscription of letters and words, which means assembling lines of words that eventually reach permanence and can be transmitted to readers (Kruse & Rapp, 2019; Kruse & Rapp, 2023; Kruse et al., "Word Processing Software: The Rise of MS Word"). To match writing and thinking, the inscription procedures must be similarly flexible as the thinking processes but still be able to ensure the permanence of the inscribed content. Typewriters were comparatively inflexible, producing fixed text lines only partially revisable. To arrive at a usable text, writers usually needed to produce several draft versions because of the medium's limited options for the removal of inscribed text until autocorrection-enabled typewriters were available. In digital technology, insertion of characters is as easy as deleting, changing, relocating, rearranging, or formatting them (see Kruse & Rapp, "Word Processing Software: The Rise of MS Word"). Word processors compress the operational space between writing, revising, designing, editing, and publishing the text to the use of a single tool. Many parts of the writing process have been automated by digital tools, unburdening the writer from some aspects of inscription in favor of focussing on the content of the emerging text. All these aspects free the writer from lower-order and often trivial activities.

Next to the lower-order aspects of handling a writing tool, another aspect makes the creation of lines of words difficult and distracts attention from the conceptual issues of content creation: the constraints of linguistic forms, orders, and conventions (Bazerman, 2013). The writer must attend to many syntactic, morphological, lexical, and rhetorical demands. Words cannot be attached to each other like Lego pieces. When a noun is exchanged, the verb usually has to be adapted. When a tempus form is changed, other tempus forms may need modification as well, and when a connector is replaced, the meaning may change and must be reconsidered and possibly rephrased. What keeps them together is a high number of different syntactic, collocative, lexical, and rhetorical conventions that are intertwined with logical structures in an often confusing way.

Digital writing tools support the assembly of words into meaningful units of thought, allowing the writer to test the connections between language and thought. Writers do not have to decide in advance about the sentence to be inscribed, as in handwriting or typewriting, but can flexibly modify the sentence in real time. Writers can also alter the chosen line of linearization flexibly, both within a sentence and between sentences and paragraphs. The writing tools have adapted to the needs of thinking-for-writing and enable the use of language for various purposes. Several tools support writers during inscription, such as synonym finders, grammar checkers, sentence completion programs, phrasebooks, or internet search tools. In addition, various tools support the revision phase of writing such as automated feedback systems or those that support human feedback; style and grammar checkers; and so on.

Digital inscription technology has offered new ways of thinking which, as Heim (1987, p. 27) has claimed, revolutionize the "transcendental intimacy of thought, word, and reality," thus reconfiguring thinking, language, and experience in a new way. Although Heim's argument is a philosophical one, we can also use it to refer

to changes in writing processes. Digital tools give way to new forms of thought development when a writing space supports the alignment of mental representations with linguistic expression. Whether we see the textual forms of thought as primary or as mentally constructed, word processors are writing spaces mediating the mental and the literal.

Van Waes and Schellens (2003), for example, studied the processes of 20 writers who wrote two texts, one by hand and one on a computer. Extensive analysis of keystrokes and recordings of the handwritten episodes revealed significant differences in the writers' processes, including the length of the pauses between moments of inscription and subsequent revision of already produced text. As the 20 participants switched modes (from handwriting to writing on the computer), the profile of their composing processes changed. This and other evidence demonstrates differences in the way that writers produce text on the computer but also gives us a window into changes in thinking processes, which are revealed by changes in text production.

Thus, what explains Heim's quality of an "intimate" relation between thought, word, and reality is probably the increasing loss of a clear border between the mental activity, the content, and the writing space in which thought is shaped. The word processor becomes an extension of the mental thinking space and successively enlarges its natural capacities. The word processor is, however, not a passive medium like the chessboard is for the players but is an agent that virtually thinks back. It not only supports thinking activities and makes the thought production smooth but increasingly adds to the production of thought and content itself (see Benites, "Information Retrieval and Knowledge Extraction for Academic Writing"; Benites et al., "Automated Text Generation and Summarization for Academic Writing").

When we consider word processors as "thinking tools," then we address this quality of using the virtual writing spaces to make thought accessible for conscious and deliberate processing. Thinking in writing depends, first, on the inscription technology and the way writers can see and manipulate their own thought by changing what they wrote. However, many technological features extend the word processor's range of activities by connecting it to the internet, to platform engines, and to the writing spaces of other writers with activities such as importing thought from external sources, checking existing material, getting and giving feedback, co-authoring papers, and bringing thought into line with other writers' ideas and statements.

3.2 Actions and Sub-actions of Writing Processes

Text production follows, as most human working processes, a temporal logic of steps to be carried out such as planning, source reading, data gathering, outlining, formulating, revising, giving and receiving feedback, formatting, editing, and publishing. Such a sequence leads from the first idea or assignment to the finished, submitted, or published text. Different from many other working processes, writing is seen as a recursive and iterative process, as Emig (1971) and Hayes and Flower (1980) have

shown. This means that the order of steps or stages is not fixed but can vary. Several steps may be carried out repeatedly and each part of the text can be revised several times. Writers learn while writing and this makes it necessary for them to adapt what is already written to what they continue to discover until the text is coherent. The arrangement of sub-actions can be adapted to individual writing strategies and thinking preferences.

The best-known process model (Flower & Hayes, 1981; Hayes, 2012; Hayes & Flower, 1980) sees writing as a sequence of cognitive activities (planning, translating, revising, transcribing), thus reducing writing to mental activities without reference to tool use or manual actions. If we look at writing processes through the lens of word processors and other digital tools, we find an increasing number of functions that support various sub-actions of the writing process (Lockridge & van Ittersum, 2020). Van Ittersum and Lawson Ching (n.d.) suggest on their website (http://cconlinejournal.org) that the writing process is not so much a static cognitive structure as a set of complex interactions among writers, their tools, and their objectives. What is called the "writing process," they add, is a system of activities that is made and re-made every time a writer writes.

Slightly simplified, understanding the writing process today means specifying which digital tool to use to perform any of the various sub-tasks. Each of the sub-tasks is connected to a certain thinking activity that once had to be performed mentally without computer support or as a paper-based activity. Candidates for a closer consideration are the following sub-actions of writing with the respective technologies supporting them:

Idea generation and invention: Even though mind and concept maps existed before the digitalization of writing, today they can be included seamlessly into the writing process and the results can easily be transferred from the tool used to the word processor (see Kruse et al., "Creativity Software and Idea Mapping Technology"). The interest in invention processes spurred the development of digital tools to aid in the composing process. These included brainstorming programs, mind maps, and concept maps. Mind maps and concept maps provide the most direct access to conceptual thinking (Kruse et al., "Creativity Software and Idea Mapping Technology") and also provide an operational model of what concepts are. Although both concept maps and mind maps reach back to the pre-digital age, they have changed their accessibility and connectedness to writing considerably post-digitalization. Both technologies are based on the idea that collecting and connecting ideas (thoughts, terms, conceptual units) is a worthwhile activity to get access to conceptual thought without being bothered by the linguistic embedding of the ideas into linear arrangement of the text.

Planning and project management: Planning tools such as Thesis Writer have been developed in the context of project management and have been imported into word processors only recently (Rapp et al., "Beyond MS Word: Alternatives and Developments"). They can be used to both draw a plan for a writing project and monitor its progress. When using planning software, thinking shifts toward the methodological meta level, forcing writers to look at their working process from the outside, and maintain focus on the temporal issues of their projects.

Outlining and structuring: Creating hierarchical outlines was one of the early functionalities of word processors. They organize headlines hierarchically and allow the creation of tables of contents. Outline generators support structuring content and organizing them both logically and thematically. Blocks of content can be moved up and down along with the respective headlines to allow for a flexible rearrangement of content. Outline generators are of great help to master the structural demands of academic papers and offer substantial support for thinking by making outlines visible and adaptable.

Literature searches, source reading, and annotating: Reference management systems revolutionized the way writers handle literature. While initially these tools copied the library card drawer with references and summaries, today they include increasingly more functionality and have expanded the opportunities for writers to engage with the relevant literature (Proske et al., "Reference Management Systems"). Writers can "collect, select, analyze, interpret, organize, and connect information of different sources," as Proske et al. explain (p. 2). Reference management systems do much more than organizing the reference section of a paper, particularly since they do not only collect references themselves but also the respective papers, usually as PDFs. They also can guide the production of the literature review and the state-of-the-art sections. These actions connect knowledge of content with rhetorical knowledge and relate both to the aim of a paper or research project. It is unclear to what extent the new technology has changed thinking along with the activity itself; disregarding the technology used, the relationship between emerging content and rhetorical knowledge is one of the most demanding of the writing process, requiring many kinds of thinking. New options for creating intertextuality are offered by plagiarism detection software (see Anson & Kruse, "Plagiarism Detection and Intertextuality Software"). Particularly when not used to find improper quotations but to inform writers about the ways they have incorporated outside literature, this kind of technology may be helpful as an aid for creating literature reviews.

Summarizing and note-taking: Reference management systems and notetaking tools have overlapping functionalities even though notetaking starts from the reading process and is less grounded in knowledge management than in the knowledge reception. As Pitura, ("Digital Note-Taking for Writing") points out, notes are elementary information units, usually of private nature, which can be used to transfer knowledge from a source into the frame of personal usage for the purpose of learning or writing. Notetaking is a basic activity for academic learning and writing alike and trains receptive abilities of text comprehension and idea generation.

Quoting, referencing, and intertextuality: Although not considered a stage of writing, the role of intertextuality is a core feature of academic discourse and was one of the early targets of digitalization (see Proske et al., "Reference Management Systems"). Access to intertextuality can be provided by plagiarism detection software which indicates all sources taken from the internet (Anson & Kruse, "Plagiarism Detection and Intertextuality Software").

Formulating: Writing is always concerned with finding the next word. Linearizing thought also means linearizing the chain of linguistic signs and interconnecting

them (Kruse & Rapp, 2023). As both activities have to be carried out simultaneously, formulating is seen as a strenuous activity. As inscription and revision can be carried out almost simultaneously, the cognitive load of formulating has been reduced, affecting thinking (Kruse et al., "Word Processing Software: The Rise of MS Word"). Tools include grammar and style checkers, digital phrase books and corpus search tools (Chitez & Dinca, "On Corpora and Writing"), and summarizing software.

Editing, publishing and submitting: Many tools and platforms offer services for checking grammar, spelling, style, coherence, and other aspects of text quality. It is an important learning task for writers to employ such digital tools to improve a text and make it publishable. Writers are not only relieved of attention to certain language features but have substantial support for them (see Shibani, "Analytic Techniques for Automated Analysis of Writing"; Link & Koltovskaia, "Automated Scoring of Writing"). In addition, digital technology along with the internet offer intermediate forms of publication, such as portfolios, that address small or medium-sized groups instead of open, unlimited audiences (see Bräuer & Ziegelbauer, The Electronic Portfolio: Self-Regulation and Reflective Practice).

Formatting, visualizing, and designing: Although it may not seem related closely to thinking, writing cannot really be dissociated from its graphical appearance. Early on, multimodality held promise for digital writers, and even if it has not fulfilled all expectations, it does provide affordances for the use of graphics, pictures, sound recordings and videos to enrich alphabetic text. What once had been the task of a professional field of graphic designers, typesetters, and printers can be done in passing by the writer.

3.3 Thinking Together: Connected Thought and Networked Thinking

While traditionally, writing was considered a rather solitary activity, digital technology has made its social dimensions more visible, accessible, and available. Activities that previously could be performed by a single writer now may be carried out collectively, with equal access to the text production process for every participating writer. But even for individual writers, digital tools offer new ways of relating to the thoughts of others and connecting to them in different ways than the traditional quotation systems.

While thinking together in pre-digital technologies happened only when a text existed as a consistent draft, today collaboration and co-authoring can start at a much earlier stage. First steps such as exploring a topic, generating ideas, and searching the literature can be produced collaboratively. More broadly, writing can be composed collectively with various roles and distributions of labour among the writers. This may lead to completely new configurations of interconnected individual and networked

thinking. For a more extended discussion of collaborative writing software, see Castelló et al. ("Synchronous and Asynchronous Collaborative Writing").

While the technologies in the last chapter support activities that have always been part of writing, in this chapter we deal with technology that enables completely new kinds of actions compared to those in the pre-digital age. Synchronous collaborative writing, joint publication in wikis, or social annotating are relatively new developments and need considerable extensions of our conceptualizations of writing.

Collaborative thinking in online word processors: The social dimensions of collaborative writing have been extensively covered in existing scholarship (for instance, Posner & Baecker, 1992; Sharples et al., 1993), which were using early digital technologies with hard-wired LAN networks to induce collaboration. With wikis and the launch of Google Docs in 2006, collaborative writing and document sharing became accessible to a large public (see Castelló et al., "Synchronous and Asynchronous Collaborative Writing", for a summary). Although asynchronous collaboration predates digital technology and has been enhanced by it, synchronous collaboration is more recent. To further support collaborative writing, advanced online word processors usually include a comment function to discuss or give feedback; visualization to highlight certain content; version control and revision history to allow the writer to go back to previous iterations; standard author roles such as "editing," "suggesting," "viewing," and "reading"; and integrated communication channels such as chat and video streaming that help coordinate the writing process.

While collaborative word processors and other tools allow for joint usage of the same digital working space, writers have to organize working processes differently than when writing solo. Issues such authorship and writer identity in digital collaborative writing conditions also deserve deep attention in research, especially in professional contexts (see Reid & Anson, 2019, for a representative case study). Next to the newly emerging roles, coordination is an essentially new demand of such tools and a group writing synchronously has to develop new collaborative writing strategies that differ from traditional writing processes (Olson et al., 1993; Olson et al., 2017; Yim et al., 2017; Wang et al., 2017). We have to assume that a considerable portion of the thinking activity has to be directed to the coordinative needs of the group situation. Writers experience themselves differently in synchronous collaborative contexts and have to adapt to the new social challenges which include a struggle for roles, competition, influence on the product, and choice of a strategy. In addition. the social nature of collaboration may lead to affective and emotional responses that are part of thinking while writing.

Wikis: As Cummings ("Content Management System 3.0: Emerging Digital Writing Workspaces") explains, wikis are CMS designed for writers to develop content and write text together. Unlike earlier wikis, today they are more flexible and can be customized as well as adapted to individual tasks by every user. They are, as Cummings explains, "no longer just about collecting and organizing information but cultivating new connections for ideation and content creation—both personally and collaboratively". Wikis are web-based working spaces that include different kinds of content, both formal and informal, connected by bidirectional links. Various kinds

of knowledge visualizations are offered and shared publishing is possible. From the perspective of thinking processes, Cummings notes that

> In these spaces, some aspects of our cognitive processes become visible through links and graphs. Because most of these digital workspaces allow users to shape and transform the space, cultivating these CMS becomes a form of thinking itself, often preceding the ideation phase of invention. As a result, our thinking can become much more visible by making it tangible. Instead of just thinking about our ideas, we can actually see the process of how our ideas came to be.

Next to the visibility of thought, the interconnection and the joint shaping of content are of interest in conceptions of the relationships between digital technologies and thinking. It seems promising for theory building to follow the idea of externalizing thought through digital writing spaces.

Portfolios: Similar to wikis, electronic portfolios are CMS designed to exchange text and offer new ways of interacting with others (Bräuer & Ziegelbauer, "The Electronic Portfolio: Self-Regulation and Reflective Practice"). Their original intention was to make student papers visible and document or communicate their development (see Yancey, 1992). In digital contexts, the interconnection to other texts, and the affordances for sharing, commenting, and reflecting, provided initial innovations. Portfolio use offers many opportunities for networked thinking and learning, as well as for group engagement in class, connecting individual text work with communication, learning, and presenting.

Social Annotation: Hodgson, Kalir, and Andrews ("Social Annotation: Promising Technologies and Practices in Writing") describe social annotation as a "type of learning technology enabling the addition of notes to digital and multimodal texts for the purposes of information sharing, peer interaction, knowledge construction, and collaborative meaning-making." Similar to the function of wikis, social annotation brings writers together in a digital working space and allows them to interact by commenting on papers of various kinds. This is primarily used for the reading and evaluation of sources which typically precedes (but may be concurrent with) the writing process to prepare and enrich the knowledge base on which a paper may be grounded. It also may be used as a reading tool for learning, not only for writing purposes. Social annotation produces a kind of interactivity between users supported by "social reading, group sensemaking, knowledge construction and community building" (as Hodgson et al., "Social Annotation: Promising Technologies and Practices in Writing", note with reference to Zhu et al., 2020, p. 262). The nature of such digital tools deepens the construction and interpretation of meaning more than any other previous writing or knowledge media.

3.4 Computers as Content Developers, Thinking Tutors, and Co-authors

Recently, computers have started to support the core features of academic writing: content production, argumentation, and summarization (see, for example, Cotos,

2014, 2015) Beyond this, they are at the edge of becoming co-authors and independent agents of text generation, thus expanding their competencies beyond supporting sub-actions to become text producers of extended and elaborate drafts (see Benites et al., "Automated Text Generation and Summarization for Academic Writing"). What does this mean for human thinking? Writers can request a document from one of the available text generation tools such as GPT-3 and will receive a fully fleshed text on a chosen topic. With this AI-based programming, the computer can move beyond a tutoring or supporting role to become a co-author mimicking what humans consider a stance or position embedded in a coherent text. Although AI-based text production systems do not "think"—in their current iteration, that are, as Bender, et al. (2021) have described them, "stochastic parrots"—they demonstrate how computers can still produce artifacts that appear to have been created by human writers, taking over the processes of text production and challenging traditional linguistic craftsmanship.

Argument construction and argument mining or mapping: Argumentation is an intellectual activity that seemed to be exclusively in possession of humans, until it was made accessible for computation (see Benetos, "Digital Tools for Written Argumentation"). Argument mining or mapping refers to technologies that scan text corpora for the rhetorical signs of argumentation, delve deep into the logic of argumentation, and make the extracted arguments available for learning and writing. They also help to design arguments and prepare argumentative writing. Computer-enhanced argumentation has challenged software developers because of its multi-faceted and discipline-specific forms but seems to be successful when reduced to its generic forms and graphically supported by diagrams (Benetos, "Digital Tools for Written Argumentation"). Although few of these digital tools have made it to the market so far, they strike at the heart of rationality and scientific inquiry. Argumentation is one of the most complex thinking activities and is key to critical thinking. Cracking its code for computation or at least for computer supported instruction would be another key aspect of the human-computer interplay that needs conceptualization and research.

Automatic text generation: Currently expanding AI-based natural language production systems will rapidly change writing and intellectual development. Like the games of Chess and Go in which computers easily outsmart world champions, text generators will eventually produce papers of higher quality than those written by university students. Even though computers do not understand what the words they use mean, they can gather relevant knowledge, make decent summaries, and excel rhetorically (see Benitez et al., "Automated Text Generation and Summarization for Academic Writing"). There is reason to fear that the interaction with the computer will lose Heim's (1987, p. 27) notion of the "transcendental intimacy of thought, word, and reality." Automatic text generation is not about the word-for-word interaction with a word processor that gently supports the writer's development of ideas. Automatic text generation puts the writer into the role of a reader of a self-generated text and, depending on satisfaction with the produced text, a possible editor. Texts are not written in the writers' own words, even if the writer initiated the process and has to make sense of its results. Language production becomes part of the computer's skills and when the need to formulate and struggle with words, collocations, and rhetoric

is passed on to the computer, an important area of language learning and meaning making is subverted. The alignment of writing and thinking made possible by the word processor will dissolve again in favour of patterns connected to the handling of complete texts with the option of revising them. It has yet to be known what the new role of humans in text production will be under these circumstances and how they can be performed, although some suggestions have already been proposed for accommodating AI-based language production systems in the classroom (see Anson, 2022; Anson & Straume, 2022).

4 Conclusions

Through digital technologies, thinking itself has become technologized and is at the edge of becoming industrialized. Opening a laptop, we find plenty of "tools for thought" (Rheingold, 1985) that support, augment, expand, or even replace human thinking. The share of automatically processed sub-tasks of writing is growing, thus transforming writers into tool users who know which button to press in order to accomplish a complex thinking activity. Digital technology changes not only the basic language and formatting skills like hyphenation, spelling, grammar, and typesetting but also higher-order processes such as translation, argumentation, and summarization. It is unclear, however, whether and to what degree writers will still know what the computer does in the background.

The computer is not only a tool that enhances writing, it changes writing itself and forces writers to adapt their thinking to a wide range of new technology-supported activities. Today, digital technology enables writers to produce text in new ways, to cooperate and communicate with more ease, and to access knowledge within seconds from myriad sources. All this upends the production logic of texts and pushes the cognitive, linguistic, social, and emotional components of thinking-for-writing in new directions. The computer, thus, is not only a supporting and comforting agent but also a challenging one. Keeping up with technological development and readjusting to new tools, platforms, and networks has become a constant task. A considerable part of thinking activities for future writers will be to explore this constant change and adapt to it.

Finally, the computer is about to take over the writing professions by becoming an agent of text production itself, thus initiating the industrialization of text production. This again forces writers to adapt to a completely new reality of academic work and thinking. Meta-skills of communication and evaluation will become necessary for supervising the computer and controlling its products.

In summary, four new dimensions surface as core issues for an understanding of the relationship of thinking, writing, and digital technology:

New thinking skills: Making use of the new technological opportunities requires a new level of digital literacy and technology awareness. Teaching and critically evaluating these new technologies, and adjusting thinking skills to them, will be equally needed.

Loss of skills: Digital writing technology may have deteriorating effects on the development of certain thinking skills, particularly because automatic computer support, such as spelling, grammar, hyphenation, collocation, choices of style or register, etc., may lead to a loss of the respective linguistic and cognitive skills that are no longer needed when the machine takes care of them. It is not clear yet how to respond to these losses and whether they can and should be replaced by new technological skills.

Cooperative interaction with the machines: It is still a challenge to conceptualize thinking as an interactive process with the computer. Licklider (1960, p. 4) was the first to write of a [hu]man-computer symbiosis as part of a cooperative interaction between both in which computers do the "routinizable work" while humans "set the goals, formulate the hypotheses, determine the criteria and perform the evaluations." Bazerman (2018) has suggested focusing on "socio-cyborgian activity systems" for human thinking, where the computers take over what humans cannot do equally well.

> This changing distribution of work means that human skills also must change. While machines will come to do what machines do best, humans must reallocate their attention and skills to do what humans do best in these socio-cyborgian activity systems. Further, humans need to develop new skills to understand, direct, and make choices about these complex networks. (p. 205)

Bazerman's conceptualization suggests a need for balance between the human and the digital, focusing on what humans can do best rather than on their deficits or disappearing skills. His metaphor helps to avoid an evaluation of digitalization in terms of wins or losses for the humans in favour of a productive collaboration or interaction between both.

New access points to intellectual development: Currently, computers are unable to perform certain aspects of human thinking, such as conceptualization, rationality, logic, disciplinarity, intentionality, epistemological reflectiveness, and metacognition. We like to group these features under the term "critical thinking"—those parts of thinking that the computer at best mimics. Critical thinking does not develop in a single course and does not result from writing a single paper but is the result of longer and more sustained educational experience and intellectual development. Relating thinking in writing to this development should be a way to arrive at new perspectives for the teaching of writing alongside whatever technological developments accrue to us.

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