Synchronous and Asynchronous Collaborative Writing

Montserrat Castelló, Otto Kruse, Christian Rapp, and Mike Sharples

Abstract Collaborative writing has been greatly stimulated by digital technologies, particularly by word processors that have made it easy for co-authors to exchange and edit texts and also led to the development of many experimental tools for collaborative, synchronous writing. When the world wide web was established, the arrival of wikis was hailed with great enthusiasm as an opportunity for joint knowledge creation and publishing. Later, cloud-based computer systems provided another powerful access to collaborative text production. The breakthrough for synchronous collaborative writing was the release of Google Docs in 2006, a browser-based word processor offering full rights to up to a hundred users for synchronous access to a virtual writing space. Next to its easy accessibility, it was the free offer of Google Docs that opened this new chapter of writing technology to a broader audience. When Microsoft and Apple followed with their own online versions, collaborative writing became an established standard of text production. In this chapter, we trace back what collaboration through writing means and then look at the new opportunities and affordances of collaborative writing software. Finally, we briefly recount the impact of early technologies before we settle on the current generation of collaborative writing tools.

Keywords Collaborative Writing · Synchronous Writing · Writing technology

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1 Background

For centuries, scholars have collaborated through writing. Charles Darwin, for example, was at the hub of an extensive network of intellectuals; his collected letters fill seven volumes. However, despite some imaginative solutions to write collaboratively (via letter, fax, and later email), until the 1920s academic papers were generally written by lone authors (Greene, 2007), and it was only in the 1990s, with the development of networked computers, that international multi-author academic writing became commonplace. Thus, the major developments in collaborative writing have arisen in the past 30 years, and this certainly is a result of various innovations in digital writing.

"Collaborative writing" is a term with many synonymous alternatives, as Lowry et al. (2004) showed, such as coauthoring, collaborative authoring, collaborative composing, collaborative editing, cooperative writing, group writing, group authorship, joint authoring, joint authorship, shared document collaboration, and team writing. We follow Lowry et al.'s (2004) suggestion to use collaborative writing as the generic term with the additional implication that today it is technologically supported collaboration. Though we mostly refer to academic and professional writing, the considerations we discuss throughout the chapter can also apply to other types of collaborative writing (e.g., school writing or writing to learn).

Theoretical foundations for research into academic collaborative writing were laid in the early 1990s, with papers on design of computer support for co-authoring and collaboration (Neuwirth et al., 1990; Sharples et al., 1993), studies on how people write together (Ede & Lunsford, 1990; Posner & Baecker, 1992), and an edited book on Computer Supported Collaborative Writing (Sharples, 1993). Taken together, these and later studies (see Olsen et al., 2017) highlight the variety and complexity of collaborative academic writing which may refer to student assignments, grant proposals, project reports, academic and scientific papers, and edited books. Academic writers (students or researchers) may start from scratch, begin with an outline, work from a prepared template, or merge and revise previous texts. Contributors may add comments, links, and suggestions but also alter or delete existing text. Participation may be balanced, or there may be a clear leader.

Some general principles and guidelines for collaborative digital writing have been extracted from this heterogeneity. Sharples et al. (1993) identified three general methods of coordinating collaborative writing: *parallel, sequential* and *reciprocal* (Fig. 1).

Parallel coordination divides the task among the writers, who each write a different part of the text according to skills or knowledge. An academic lead may then revise these into a consistent work. This is the typical coordination for an edited book or conference proceedings.

Sequential coordination is a production line. The first person in the line takes the writing task to the initial stage of production. That person hands the part-completed product on to the second person who works on it to the second stage and so on down the line. Sequential working fits a "plan—draft—revise" approach to writing,

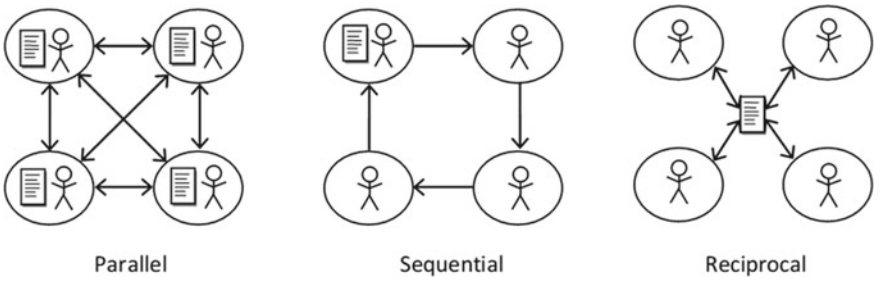

Fig. 1 Methods of coordinating collaborative writing (Sharples et al., 1993)

with the first person creating a plan, the second composing the first draft of the text, the third revising or extending the text, and so on through as many revisions and extensions as there are writers. With two or three authors, the draft can be handed back and forward, or round in a circle.

In Reciprocal coordination all the partners work together on a shared document, watching and mutually adjusting their activities to take account of each other's contributions. Reciprocal working can be used to compose or to revise. It can be synchronous, with all the writers suggesting ideas and revisions while one or more individuals type, or asynchronous with a shared computer file that everyone can write to or amend. Synchronous tools usually make all writing and editing activities of the participants visible to all others, and record them to be traced back. Web-based storage of shared documents has now blurred the former clear distinction between synchronous and asynchronous writing.

Some early collaborative writing tools imposed roles on contributors such as "co-writer" and "commenter" (Leland et al., 1988; Posner & Baecker, 1992). Contemporary tools such as Google Docs or Office 365, however, leave it to the participants to negotiate roles. Leadership is another general principle for collaborative writing. A participant can take over the lead and coordinate the writing activities (for example, through exchange of emails or a shared calendar), allowing contributors to add comments and suggestions, leaving formatting to a late stage so that authors can set down thoughts without worrying about visual appearance, and keeping a clear record of revisions so that credit can be given to contributors and changes can be undone (Sharples, 1992).

While in individual writing, the working habits of a single person determine the course of the writing process, in collaborative writing a collective writing process has to be developed. Beck (1993) explored the experiences of collaborating writers, with a focus on how they discuss content and structure of the document during writing. She found that the writing teams she studied had a range of leadership styles, fluctuations in membership, and a dynamic group process whereby tasks, leadership and responsibilities were negotiated as the writing progressed.

Posner and Baecker (1992) suggested a taxonomy to explain joint writing processes, which they derived from interview descriptions of project work. The taxonomy combines four different categories, each providing a different perspective

of the joint writing process: roles (who is doing what), activities (actions performed while writing), document control methods (how the process is coordinated). It also describes five collaborative writing strategies that experienced writers deploy for text creation:

- *Single Writer Strategy:* One team member is writing the document while the others assist.
- *Separate Writers Strategy:* The document is divided into separate units and each is written by a different team member.
- *Scribe Strategy:* Group members work together and one of them writes down the results of the discussion.
- *Joint Writing Strategy:* Group members decide jointly on every aspect of the text, word by word.
- *Consulted Strategy*: A consultant for whom a writer or team works is involved; this strategy can be combined with any of the former constellations.

Based on their findings about how writers produce collaborative texts, Posner and Baecker (1992) elaborated a set of design requirements that collaborative writing systems should support, which focused on the need for flexible and permissive tools, allowing groups to transition smoothly among different strategies and processes, technologies, and between synchronous and asynchronous work by group members. As we will specify, many of these requirements have been addressed by digital tools designed to support collaborative writing in the past two decades.

2 Collaborative Writing Software: Core Idea

Software for collaborative writing was developed first in the 1980s. Posner and Baecker (1992) referred to seven different tools: Aspects, ForCom, GROVE, PREP, Quilt, SASSE, and ShrEdit, all of them released between 1986 and 1992. A decade later, Noël and Robert (2003) reported on 19 web-based systems for collaborative writing, most of them already abandoned by the time their report was written. Those systems were research projects and not designed or marketed for commercial use, with all that entailed such as integration with pre-existing writing tools.

Most of these early collaborative writing systems were limited in their support for coordination, annotation and versioning. Noël and Robert refer to the coordination methods shown in Fig. 1 and indicate that only one system, REDUCE, supported synchronous reciprocal writing. Some systems provided no facilities for commenting, others failed to let users save and restore different versions of a document. As the authors indicated, in 2003, "since none of the presently available systems offer even a majority of the features and properties that an ideal collaborative writing system should offer, there is at the least an obvious need for improvement" (Noël & Robert, 2003, p. 260). Clearly, the idea of collaborative, synchronous writing had a fairly long incubation time until it was channeled into the technologies of today's major writing platforms.

The modern version of collaborative writing started in 2006 with Google Docs allowing co-writers to work together on a shared web document, thus offering completely new opportunities for synchronous and asynchronous collaboration in writing. In 2005, Google had bought Sam Schillace's web-based word processor "Writely" from which Google Docs was developed, also by Schillace. A first version of Google Docs was soon released in a beta version. The similarity to the Microsoft Office Suite was clearly visible, but the functionality of a browser-based word processor along with document sharing and collaboration differed considerably from it. All that users needed were a Gmail account, a browser and an internet connection to start writing collaboratively. The key innovation of this software was its ability to let several writers work in the same document and at the same time. A cloud-based file sharing system was also included. In the last decade, Google Docs has become the default tool for collaborative writing and co-authoring (Krishnan et al., 2019), though in the current post-pandemic scenario co-writing practices have moved across multiple artifact ecologies (Larsen-Ledet et al., 2020). Alternatives are considered in the next section of this contribution.

Traditionally, collaborative writing software refers to at least three aspects of co-authoring: (1) joint production of text which provides several writers with access to a document and equal rights in its creation and handling, (2) revision of text, which may consist in changing any part of the text and inserting corrections and (3) shared commenting and annotation of the text which establishes a metacommunicative level for the writers to negotiate plans and intentions. The three elements can, but need not, coincide in actual writing processes but still form a standard in the latest versions of word processing software such as Google Docs and Office 365. Additionally, collaborative writing software usually contains what most sophisticated single-author writing software offers, such as functionalities to track changes and to restore former versions. The server-side storage of text, as introduced by Google Docs, made it possible to track the text development, including all changes, and make it accessible to all users.

Synchronicity of writing, along with access to the same writing space, adds a layer of complexity to writing since it implies managing not only different writers' schedules experiences, and disciplinary backgrounds but also their intentions. It may be necessary to make these different dimensions explicit, as shown by recurrent findings regarding the benefits of using oral chats and discussions during collaborative writing, especially in synchronous writing (Li, 2018; Storch, 2019; Talib & Cheung, 2017).

Google Docs was not the end of the development but a beginning that added a dimension to literacy by coordinating collective text production in new ways with intellectual and professional activities. Since Google Docs now allows live synchronous as well as asynchronous ways of working, groups of writers have a wide and heterogeneous range of options which may need to be coordinated. Consequently, former asynchronous technologies like MS Word or LaTeX are still used for collaborative writing (Larsen-Ledet et al., 2020) making it a heterogeneous technological field.

3 Main Digital Products to Support Collaborative Writing

By far the most widespread tools for collaborative writing are Google Docs and Word 365 which provide similar functions to synchronously create and edit documents, make comments and track revisions (Larsen-Ledet, 2020). Wikis enable collaborative authoring and editing of hypertext web documents—the most popular of these is probably Wikipedia—but, in many cases, require authors to learn a markup language. Microsoft followed Google with a cloud-based version of Office in about 2013 under the name "Office 365". In a next step, Microsoft created MS Teams (launched in 2017), a collaboration platform into which the Office suite was integrated. It then changed the name of Office 365 to Microsoft 365. MS Teams is modeled as business software to organize communication within organizations. Integrated into the Teams platform, in addition to text communication, were Sharepoint (to share documents), a streaming functionality (to replace Skype), a phone service, and the former office software, all with collaboration functionality.

Different from Google Docs, MS Word can still be used locally but then needs synchronization with the cloud-based version of the text via Onedrive if several authors want to work on the document. Google, in turn, included a local version of its cloud-based word processor to enable offline writing. MS Teams allows to create "teams": groups of users who can share a large palette of documents and services both within an organization and externally. The number of such services is exploding and so is the number of still projected apps as is shown in the Microsoft roadmap at: https://www.microsoft.com/en-us/microsoft-365/roadmap?filters.

Google countered MS Teams with an expansion of its G Suite to an office package called "G Business" (launched in 2020) offered commercially to companies. It includes Gmail, Drive, Docs, Sheets, Slides, Forms, Calendar, Google + , Sites, Hangouts, and Keep.

Both MS Teams and G Business have reached a new level of complexity in which writing covers only a small fraction of a much larger kind of collaboration in business, science, or education. The focus of the technologies has shifted from the tool level to the organizational level and from text management to project management. It has yet to be discussed, what the integration of visual, oral, and textual communication devices in one platform means and to what kind of mode-crossing interactions it leads. The use of these collaborative organizational tools exploded during the pandemic when face to face collaboration became extremely limited. The level of adoption and also experimentation with a range of technologies offering very different affordances for users may have far-reaching consequences if their use persists.

Alongside Microsoft and Google, the following tools have been developed and are still available:

- *EtherPad* is one of the oldest publicly available, free collaboration tools in which the contributions and changes of each writer are highlighted in a different color. Limited functionality and basic design make it easy to use but restrict more complex editing activities. It is designed to be provided as Software as a Service.

- *Quip* is a complex business platform maintained by Salesforce to optimize sales processes. It connects documents, data, and collaboration.
- *Dropbox Paper* is a newly created collaborative software from the Dropbox company which so far has been known for its document-sharing services.
- *Tracer* is a tool to measure and visualize student engagement in writing activities by analyzing the behavioral patterns of students as they write (Liu et al., 2013).
- *ShareLaTeX* (now part of Overleaf) is for scientific collaborative writing of LaTex documents.
- *Final Draft* is a collaborative tool for screenwriting.
- *Evernote* supports shared note-taking.
- *ClickHelp* is designed for technical writers.
- *GitHub* provides a shared tool and repository for coders. The functionality of GitHub to facilitate incremental development (repositories with branching and version control), feedback (pull requests and annotation) and collaboration (access control and sharing) offers many opportunities for writers of other things besides code. Within GitHub individual writers can avail of affordances to structure text and manage iterative versions of their writing with the built-in version control but they can also avail of the collaborative opportunities afforded by the platform. Collaboration can be controlled or restricted through sharing permissions with other users and using pull requests for others to review and comment on their writing. It can also be much more open by making writing public or "open source" in the sense that others can contribute and modify the writing. One crucial difference of writing with GitHub from other tools is in text formatting. GitHub is not a word processor and typically text is written in plaintext and uses MarkDown "code" to indicate formatting requirements such as italics or headings. This can then be rendered according to the style guides or requirements of the publishing medium (e.g. pdf, xml, etc.) effectively separating the formatting process from the writing. The version control, permissions and annotation functions which are so critical to software development are equally valuable tools for writers of text rather than writers of code.
- *MediaWiki* is the leading platform for creating and editing wikis, including Wikipedia.

Looking at this long list, it becomes obvious that collaboration ability is not only a quality of specialized writing tools but a standard that more and more applies to all platform-based tools. Overviews and comparisons of collaborative writing software can be found at https://compose.ly/for-writers/online-collaborative-writing-tools/ and at https://zapier.com/blog/best-collaborative-writing-apps/.

4 Collaborative Software Functional Specifications

Functionalities that can be found in collaborative software include the following:

- *Simultaneous access to a word processor:* Writers can access independently (or by invitation) a shared, virtual writing space and write, comment, or revise text. They can see what others write, and change it in real time.[1]
- *Comment function:* Writers can make comments, answer comments, or delete them.
- *Visualization:* Means of highlighting changes in texts, individual contributions, and document history.
- *Roles for users:* The roles may be specified by the software like "read", "write", "edit", "comment" with the respective functions available or restricted. It is usually the document owner who decides on the roles.
- *Security and privacy measures:* Selective access to defined members or groups.
- *Version control and revision history:* Most recent tools record all changes, usually including time stamps, and allow users to go back into the text's history to restore former versions.
- *Integrated communication channels:* Chat or video streaming for a better coordination of writing have become standard. Writers need coordination beyond the text fields and the comment functions.
- *Export functions:* Export of documents to various formats and operating systems is necessary to allow for an exchange with different systems.

A particular challenge to collaboration software development is connected to the visualization of individual contributions. Arguably, seeing what every co-author has contributed is a prerequisite to understand collaboration but even more so to understand text development (what has been added, what changed, what deleted?). In this respect, Microsoft relied on its traditional way of tracking changes by highlighting contributions in different colours. As this may get confusing, changes may be hidden so that writers can read or write in a clean text version. Text markups can be accepted or deleted locally or for the whole document. Google Docs also uses colours to mark individual contributions but later introduced comment-like text fields at the margin which appear automatically when something is added or deleted. They contain name, date and kind of change. Additionally, Google developed a functionality called "version history" opening on a side panel on request, which offers a list of all former versions and allows to restore any of them. Although version history functionality has been present in many tools, what is new in Google and also Microsoft Sharepoint is the dynamic and ongoing versioning that does not require writers to lock them, as well as the relatively easy way to come back and restore previous versions.

[1] Changes may not be available in real-time to other authors when writers work in an MS Word document that is synchronized via OneDrive.

These visualization solutions do not live up to what technology today could offer. Southavilay et al. (2013) developed and tested three visualization approaches:

- a revision map, which summarizes the text edits made at the paragraph level, over the time of writing;
- a topic evolution chart, which uses probabilistic topic models, to extract topics and follow their evolution during the writing process; and
- a topic-based collaboration network, which allows a deeper analysis of topics in relation to author contribution and collaboration.

Another way of visualizing text progress in collaborative writing is DocuViz (Wang et al., 2015). The primary aim of this software was to develop a research tool to investigate the patterns of collaborative creation of documents and their correlation to text quality. Additionally, the tool is expected to enhance authors' awareness and knowledge of their own group writing processes, and thus, may serve pedagogical purposes (Wang et al., 2015). The current version, DocuViz 3.8, is a free productivity extension to Google Chrome. It has been used in several studies to assess its functionalities and efficacy both as a research tool to know more about how collaborative writing processes unfold and as an educational tool for raising awareness about these processes among co-writers. In both cases, the tool has been mainly used retrospectively as a way to evaluate writer's contributions, texts' evolution and characteristics of different composition processes through time (Krishnan et al., 2019; Sundgren & Jaldemark, 2020; Yim et al., 2017).

5 Research on Collaborative Writing Software

Successful collaborative writing depends on a highly complex cluster of individual and socially-shared regulatory movements (Castelló, 2022; Sala-Bubaré & Castelló, 2018). Research, so far, has only slowly begun to move beyond the study of asynchronous collaboration such as in feedback, peer reviews, and cooperative text production (cf. Olson et al., 2017; Storch, 2019). And we can assume that technological development of collaborative software has not come to a halt as Wang et al. (2017) predict. Still, today there are standard solutions to which writers are habituated and which can be studied in naturalistic settings (e.g., Google Docs documents' history or extensions) without prototype or bespoke technology and complicated experimental designs (Yim et al., 2017). Regarding methodology, qualitative retrospective tools (e.g., interviews or self-reports) have been predominant together with quantitative analysis of writers' interactions (e.g., comments, chats, discussions), and text evolution (e.g., number and type of edits, inclusions, revisions in successive drafts) (Larsen-Ledet, 2020; Yim & Warschauer, 2017).

When the first specialized software for collaborative writing was developed in the 1980s and 1990s (see Posner & Baecker, 1992, and Noël & Robert, 2003, for overviews), research focused primarily on comparisons with cooperation in conventional writing technology (paper and pencil, word processors). Olson et al. (1993)

used an experimental collaborative text editor called ShrEdit to facilitate cooperation among three-person workgroups of designers. They found that they produced fewer but better ideas. They suggested that this may be credited to a more efficient way of focusing on core issues and a decrease in wasting time when trying to get an understanding of what was going on when deciding together what should be written down and how.

A subsequent set of studies looked for affordances of different tools and technology supporting collaborative writing. One of the first attempts was conducted by Cerratto (1999), who compared collaborative writing between two groups of eight students working over 15 days. One of them used MS Word plus E-Mail, the other used Aspects, a collaboration software with synchronous writing and a chat function. They found that the group using Aspects produced lower-quality text and needed more time. They assumed that it was the group's higher coordination effort and their inexperience with collaborative software that was responsible for this result. The success of the MS Word group seemed to result from their familiarity with the tools used. In a second study of Cerratto and Rodriguez (2002), one group using MS Word to write a report sitting together in a room (so that they could talk things over) was compared with a remotely working group using Aspects. The results repeated the outcome of the first study. They conclude that not all kinds of writing tasks are equally well suited for collaborative writing tools.

Lowry and Nunamaker (2003) compared their collaborative synchronous writing tool, Collaboratus, with MS Word in a study with two collaborative writing conditions. Results indicated that the writers in the synchronous condition fared better, i.e. produced longer and better documents. The authors credited those results to some characteristics of their writing tool which provided a better basis for planning, an easier coordination, and an increased collaboration awareness. Besides differences in the training conditions (longer in the Lowry and Nunamaker's study), contrasting results for Aspects and Collaboratus can probably explained by some advanced features of Collaboratus such as the Asynchronous and web-based support and the tool orientation to parallel-partitioned work, which has been shown to greatly increase CW productivity.

Another focus of early research was the dynamics of collaboration and the related use of the tools' functionalities. Erkens et al. (2005) studied pairs of students in secondary education when writing three argumentative essays using the TC3 (Text Composer, Computer supported and Collaborative) collaborative environment. Their focus was on task-related planning activities by analyzing the chat entries. One target was collaborative coordination under various conditions, which were defined by the additional tools offered: an outline generator, a diagram tool (similar to concept mapping), a personal note pad (invisible to the others), and a tutorial on the technology use. The control group used TC3 without the additional features. Results showed little connection between the additional technologies offered and the text quality. They found that 55% of the interactions were devoted to coordination between task related strategies, cooperative intentions and communication processes during collaboration. It was the quality of these complex interactions that were responsible in large part for the text quality.

Interesting as the results of these early studies may be, it is difficult to generalize from them for two reasons. First, the tools were less developed than today, hardly comparable among each other, and of unclear quality. Second, the participants in the studies were not familiar with the new tools. Students were usually instructed in how to work with the software, but it is hard to claim this is familiarization since their level of expertise with the tools was not formally reported or assessed.

The next generation of studies used the commercialized tools from Google, Microsoft, or Apple to which academic users are usually acquainted. Today, the problem seems to be that even the best writing software will not find acceptance from all writers. Surveys about collaborative writing show at least some reservation if not resistance against the new collaborative technology or some of its functions (Wang et al., 2017). By now, however, users have had enough time to familiarize themselves with the basic appearance and functionality of the new technology such that newer studies can look at differential reactions and work patterns without asking the users into the computer lab. In practice, there are still a variety of synchronous and asynchronous tools in use (Larsen-Ledet et al., 2020) and the associated variety in practices adds a layer of complexity to research on collaborative writing in situated scenarios.

In recent years, the research focus has shifted from proving the tools' benefits or affordances to exploring and assessing the variation of writers' processes and products when writing collaboratively using digital tools. At the undergraduate level, Yim et al. (2017) explored the different strategies of synchronous collaboration by 82 students in 45 Google Docs documents and evaluated the influence of these strategies on the emerging texts. They classified the general interaction along the model of Posner and Baecker (1992, see Introduction) using DocuViz visualizations and confirmed the four distinctive strategies:

- *Main Writer* (called *Scribe* in Posner & Baecker): One participant dominates while the others remain in the background and add little;
- *Divide and Conquer* (called *Separate Writers Strategy* in Posner & Baecker): Writers divide the text into parts and work independently on them;
- *Cooperative Revision*: Parts are written separately but then revised by others;
- *Synchronous Hands-on* (called *Joint Writing Strategy* in Posner & Baecker): Sentences are created together by simultaneously extending each other's text.

Posner & Baecker's *Consulted* strategy did not apply as there were no consulting relationships among the students. The Cooperative Revision style was most common (40%), followed by the Main Writer style (31%), the Divide and Conquer style (20%), and the Synchronous Hands-on style (9%). Contrasting to frequency, the *Divide and Conquer* style tended to produce better quality text whereas *Main Writer* had the lowest quality scores. Moreover, balanced participation and amount of peer editing led to longer texts with higher quality scores for content, evidence, but not organization or mechanics. Out of the 15 groups, only six of them maintained the same style across the three documents. So, as reported previously by Beck (1993), change seems to be natural and not confined to certain group structures.

Still at the undergraduate level, Olson et al. (2017) studied 96 documents written by students in Google Docs in groups (mostly groups of four). The documents were recorded for all group members at a granularity down to single keystrokes with timestamps. Measures were developed to quantify the amount each student had contributed to the text and to determine the extent to which collaboration was synchronous or asynchronous. The data were further visualized using DocuViz and correlations were finally calculated between type of use, text collaboration and assessment of credit. The results showed that students produced text both synchronously and asynchronously. Some students even produced text exclusively synchronously. Only five documents showed no evidence of synchronous collaboration. In 77% of the documents, all members participated in writing the document, while for the remaining 23% some of them were not seen in the document history ("slackers"). For the majority, the participation rate was fairly even and only one group had a writer who usurped the writing process. A more balanced participation was correlated to document quality. In 81% of the documents, there was clear leadership, however, the leaders often changed when a new paper was written. Clear leadership contributed substantially to the writing quality. Only in 37% of the documents was the commenting function of Google Docs used. Often, comments were written into the document. Surprising for the authors was the fact that a high rate of collaborative writing took place and the participants did not distribute work to write privately, then upload their text.

Moving to graduate level and professional writing, Larsen-Ledet et al. (2020) looked at how and why a group of 32 co-authors (13 master students and 19 researchers) use collaborative writing tools working in long term projects. Through qualitative analysis, they identified three kinds of technology related to the kinds of media used in their sample:

- *Collaborative home,* when writers share an online platform which documents and synchronizes their work (e.g., Google Docs);
- *Repository*, when collaborators decide on a common service for storing and exchanging documents (e.g., Dropbox or Google Drive); and
- *Hand-over,* when co-writers decide on a file format and then share the text via email.

It would be wrong, therefore, to identify collaborative writing fully with tools like Google Docs. Collaboration also involves sharing materials and interim text as objects of work, thus collaborating on the joint understanding of the text-to-be. Those results may enrich the original discussion of methods of writing collaboratively (Sharples et al., 1993) by adding the continuum of synchronous/asynchronous modes of writing to the methods of coordinating collaborative writing. Thus, nowadays collaborative writing requires attending to and taking decisions on these two planes: synchronicity and coordination. Co-writers' decisions and actions on these planes may result in diverse processes: (a) synchronous but uncoordinated (everyone writing at the same time but in their own way); (b) synchronous and coordinated (writing together in a collaborative way at the same time); (c) asynchronous and uncoordinated (leaving a document in a shared space so that people work on it in their own time and way); or (d) asynchronous and coordinated (handing over document to another writer

to achieve a particular goal with it). To what extent these processes relate to different outcomes and text quality in real contexts is still a pending issue for research in the field (Larsen-Ledet, 2020).

Moreover, in their review Talib and Cheung (2017) conclude that the regular and frequent use of collaborative tools (both synchronous and asynchronous) in pedagogical settings helps students to redefine writers' ideas of ownership, and provides new insights into sharing ideas and clarifying thoughts throughout communication at all educational levels (schools and universities). They make three general claims which they see supported by an analysis of 68 empirical studies published between 2006 and 2016:

1. Technology has facilitated collaborative writing tasks.
2. Most students are motivated by an improvement in their writing competencies in collaborative writing tasks.
3. Collaborative writing is effective in improving accuracy of student writing and critical thinking.

Accepting these general claims, it seems justified to claim that not only our understanding of writing competences has to be remodeled but also that completely new opportunities of teaching academic writing have emerged. Collaborative writing, obviously, is not an add-on to writing but has changed its substance and nature by making it a new field of interaction that feels natural in a digital world.

The educational impact of collaborative writing technology has also been specifically explored by research on L2, ESL or EFL writing. In their reviews, Li (2018) and Storch (2019) highlight how synchronous tools such as wikis and Google Docs impact on three main strands. First, tools impact on the ways interaction unfolds during the writing process that can range from cooperative and collaborative to directive/defensive ones. Besides, digital interaction during writing is complex and includes a variety of channels (textual but also oral through synchronous chats) to discuss and comment on the writing processes and text evolution. Second, impact is also observed on the characteristics of the writing products, which tend to reach higher scores when produced using Web 2.0 tools such as Google Docs. Third, the students' satisfaction and implication were also higher when writing collaboratively using those tools.

Still in the ESL field, a recent review (Yee & Yunus, 2021) has looked at the most widely used tools in enhancing collaborative writing during COVID-19, when virtual learning and writing was not a choice. The results revealed that Google Docs, besides being the most significant collaborative tool, enable students to improve writing processes and content when writing is combined with the co-authors' online discussion. This is an interesting point considering previous research results on coordination being the critical factor for text quality in collaboratively writing. It is plausible to assume the online discussions facilitate co-writers' coordination actions in the absence of any face-to-face options.

6 Future Directions for Research

Current challenges for research on collaborative writing relate to understanding how writers navigate through different technologies and why they prefer some tools above others at certain points in the writing process. Larsen-Ledet (2020) applied the notion of artifacts ecologies to explain writers' motivation to transition among tools. She distinguished four types of motivation based on functional, communicative, aesthetic and personal reasons to alternate tools when writing collaboratively. Still, relevant issues remain unexplored regarding: how those transitions help co-writers to progress in their collaborative endeavour; to what extent authorship is changing depending on the type of co-writer dynamics supported, or enhanced by, technology; and how the cognitive, social and emotional regulation unfolds when technology mediates collaborative writing processes. All of these are crucial both for technology development and theoretical integration when it comes to collaborative writing.

7 Conclusions

Collaborative writing has increased rapidly in academic and professional settings in the last three decades, in parallel with the development and popularity of asynchronous writing tools that facilitate flexibility and awareness of the co-writers' activity during the whole writing process. The lockdowns and restrictions derived from the COVID-19 pandemic have clearly accelerated this already existing trend. Technology has allowed for the creation of joint mental digital spaces when writing collaboratively, either synchronously or asynchronously. Moreover, international networked computing, the worldwide web and additional services such as automatic translation have opened new possibilities for collaboration in writing, by large multinational teams, with rapid development of documents.

Despite the increasing practices of collaborative writing and the related use of digital writing tools, research on collaborative digital writing is still scarce and mainly focused on undergraduate students. The research evidence that is available would strongly suggest that using digital tools can contribute to co-writers' efficacy and text quality. However, there is a lack of studies focusing on analyzing how tools impact on collaborative writing processes and to what extent that impact might contribute to writers' awareness and effective regulation of those processes. Issues such as to what extent collaborative writing processes and products are mediated by particular technologies or how co-writers' reflection, knowledge transformation or critical thinking unfold through digital collaborative writing are still open.

While collaborative software certainly provides opportunities to facilitate truly collaborative thinking, it seems clear that in order to avail themselves of these opportunities, users need certain competencies and abilities. Based on the available evidence, among the most urgent ones to facilitate processes and improve products are: knowing how technology works (e.g., how it is used, set up); working together

and accepting others' writing processes and logics; extending feedback rules for collaborative writing; and becoming sensitive to different roles co-writers may have in text production.

Issues such authorship and writer identity in digital collaborative writing conditions also deserve a deep attention of research, especially in professional contexts. While in the early phase of collaborative writing (in the 1990s) there were attempts to impose author roles and identities (e.g., "co-writer", "commenter"), it was soon realized that for most writing these identities need to be fluid and managed by the writers, not imposed in advance. Current writing tools offer "lightweight" roles, such as "editing", "suggesting", "viewing" that can be changed as the writing progresses. What does this mean for the self-identity of a writer? Has this collaborative process changed the nature of identity and authorship either by expanding or contracting it? Moreover, synchronous tools facilitate writers to position themselves differently during writing and adopt a variety of roles (readers, reviewers and writers) when writing. That means writers need to coordinate and regulate the writing process (e.g., assign reviewers, set schedules) in some cases outside the writing tool and in an explicit way (Larsen-Ledet, 2020). Depending on the strategy followed during the writing process, it may be difficult for co-writers to have a sense of authorship.

In sum, a fascinating agenda for IT developers and writing researchers is emerging that might drive integration of existing evidence and formulation of new, relevant questions to build joint empirical and theoretical knowledge on collaborative digital writing. It is also possible that research on digital collaborative writing should not try to understand incremental change but account for the emergence of completely new phenomena. Success in such endeavor requires interdisciplinary dialogue and joint efforts of usually dispersed involved collectives such as researchers, trainers and developers. This book represents a sound initiative to move towards this interdisciplinary and integrative dialogue.

8 Tool List

Tool	Description	Reference and/or URL
ClickHelp	Designed for technical writers	https://clickhelp.com/
Dropbox Paper	A newly created collaborative software from the Dropbox company which so far has been known for its document-sharing services	https://www.dropbox.com/paper/start

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Tool	Description	Reference and/or URL
EtherPad	One of the oldest publicly available, free collaboration tools in which the contributions and changes of each writer are highlighted in a different color. Limited functionality and basic design make it easy to use but restrict more complex editing activities. It is designed to be provided as Software as a Service	https://etherpad.org
Evernote	Supports shared note-taking	https://evernote.com/intl/en
Final Draft	A collaborative tool for screenwriting	https://www.finaldraft.com/
GitHub	Provides a shared tool and repository for coders	https://github.com/
MediaWiki	The leading platform for creating and editing wikis, including Wikipedia	https://www.mediawiki.org/wiki/MediaWiki
Quip	A complex business platform maintained by Salesforce to optimize sales processes. It connects documents, data, and collaboration	https://www.salesforce.com/products/quip/overview/
ShareLaTeX	Now part of Overleaf, is for scientific collaborative writing of LaTex documents	https://www.sharelatex.com
Tracer	A tool to measure and visualize student engagement in writing activities by analyzing the behavioral patterns of students as they write	Liu et al. (2013)

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