Dec 11th, 12:00 AM

Supporting Human Cognitive Writing Processes: Towards a Taxonomy of Writing Support Systems

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Completed Research Paper

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Abstract

In the field of natural language processing (NLP), advances in transformer architectures and large-scale language models have led to a plethora of designs and research on a new class of information systems (IS) called writing support systems, which help users plan, write, and revise their texts. Despite the growing interest in writing support systems in research, there needs to be more common knowledge about the different design elements of writing support systems. Our goal is, therefore, to develop a taxonomy to classify writing support systems into three main categories (technology, task/structure, and user). We evaluated and refined our taxonomy with seven interviewees with domain expertise*, identified three clusters in the reviewed literature, and derived five archetypes of writing support system applications based on our categorization. Finally, we formulate a new research agenda to guide researchers in the development and evaluation of writing support systems.*

Keywords: Writing Support System, Sociotechnical Systems, Cognitive Writing Processes, Taxonomy

Introduction

Over the past few years, there has been a remarkable surge in the advancement of innovative methodologies within the field of artificial intelligence (AI), specifically focusing on machine learning (ML) and natural language processing (NLP). Especially in NLP advancements in transformer architectures (Yates et al. 2021) and large language models (LLM) (Kasneci et al. 2023) have led to a plethora of design and research on a novel class of information systems (IS) called writing support systems, which help users to plan, write and revise their text (Gero et al. 2022). These systems not only bear the opportunity to revolutionize the way we write texts, e. g., for communication, but also systems such as Grammarly or DeepL, are being used already frequently in our daily work and learning routines (Karyuatry 2018). Furthermore, writing support systems go beyond simple language correction or translation; they provide comprehensive support throughout the entire cognitive writing process, including language nuances and grammar checking (e. g., Clark et al. 2018). The introduction of writing support systems has the potential to make the writing process more engaging and impactful (Li 2021). These systems are becoming increasingly ubiquitous and are expected to shape the future of writing. According to a report by Fortune Business Insights, the global natural language processing market is projected to experience substantial growth, with a compound annual growth rate of 29.4% (Fortune Business Insights 2022). The market is expected to reach USD 127.26 billion by 2028, indicating significant economic potential. However, to create effective value for users, writing support systems encounter numerous challenges. The process of writing encompasses diverse stages and objectives (Flower and Hayes 1981), and a writing support system must accommodate these requirements (Gero et al. 2022). Challenges also arise from diverse writing styles and levels of proficiency (Singh et al. 2022). The desired outcome of a writing support system is not only to produce understandable and correct writing but also to ensure credibility (Hyland 2002). Thus, writing is not only the production of text, but can be understood as a complex cognitive process that requires different thinking and writing strategies (Flower and Hayes 1981). Especially from an IS perspective, structured design knowledge is needed for IS researchers and practitioners to design, develop and compare writing support systems and their impact on humans' different cognitive writing phases. However, the availability of a structured design guide for researching and evaluating writing support systems from an interdisciplinary IS perspective is rather scarce. Existing structured classifications for writing support systems only focus on specific domains (Frich et al. 2019; Strobl et al. 2019) or neglect the social subcomponents corresponding to IS (Gero et al. 2022). Additionally, existing classifications often lack to address the emerging field of LLM and generative AI such as GPT-3 or ChatGPT (Brown et al. 2020). These models have grown exponentially in size, knowledge, capabilities, and performance in recent years and hence bear new possibilities of use e. g., for education and writing support (Kasneci et al. 2023). Nevertheless, there still needs to be more significant research on how to effectively implement these new possibilities and incorporate them into a structured classification from a sociotechnical perspective (Bostrom and Heinen 1977). Hence, a structured classification, e. g., in the form of a taxonomy, could assist IS researchers and practitioners in designing and evaluating writing support systems more effectively. Furthermore, it can contribute to the theoretical understanding of how different technological embodiments may impact specific outcome variables. Here IS research can offer an interdisciplinary view with a sociotechnical perspective of writing support systems (user, technology, task and structure) (Bostrom and Heinen 1977). We have chosen to adopt the sociotechnical perspective by Bostrom and Heinen 1977 to include the two-way interactions between social and technical systems (Orlikowski 2000), which are especially important in the interaction of users with writing systems. Neglecting these interactions can lead to errors in information system design and affect system performance (Bostrom and Heinen 1977). Given the absence of this perspective in existing IS research taxonomies (e. g., Frich et al. 2019; Gero et al. 2022; Strobl et al. 2019), therefore, the focus of this paper is to address the following research questions:

RQ1: *What are the dimensions and characteristics of writing support systems from a sociotechnical IS perspective?*

RQ2: *How do the usage patterns of these characteristics across empirical studies contribute to the identification of clusters and archetypes of intelligent writing support systems?*

To answer these research questions, we conducted a systematic literature review (Webster and Watson 2002) and developed a taxonomy of design elements of writing support systems (Kundisch 2022; Nickerson et al. 2013). The first step involves identifying and categorizing the dimensions and characteristics of writing support systems based on 86 papers that we have identified in the literature research. Based on these findings, we developed a taxonomy of design elements for writing support systems that delineate different system configurations from an interdisciplinary IS research perspective. In the second step, we apply the taxonomy to identify connections and interdependencies among the dimensions and characteristics through the utilization of cluster analysis (Jeyaraj et al. 2006). Finally, we found eleven dimensions with 49 characteristics, providing IS researchers and practitioners with a clear structure of design elements of writing support systems. Our results shed light on the different clusters of applications of writing support systems (see Table 4). Using the clusters, we've identified five archetypes (A1-A5), which are unique system classes from various application areas. In conclusion, we analyze the outcomes and extract implications for a future research agenda. These offers IS researchers exciting opportunities for writing support systems.

Theoretical Background

Cognitive Process of Writing

To comprehend the mechanics of writing, we will focus on the theory of Flower and Hayes 1981 which explains the cognitive approach to writing. Instead of focusing on writing as only a creative endeavor, writing is viewed as a complex system of inter-working cognitive processes (Hodges 2017). These processes are hierarchically structured and interwoven. Writing is an intentional process driven by goals. As writers engage in writing, they construct a hierarchical network of goals that guide their writing process. These goals are formulated and accomplished through sub-goals. If necessary, writers adjust their goals based on their learning throughout the writing process. According to Flower and Hayes 1981, the act of writing comprises three fundamental elements: the writer's long-term memory, the writing process itself, and the task environment. The task environment encompasses all contextual factors present at the onset of the writing task. Elements such as the topic, audience, and motivational cues influence the writing process. Additionally, the previously produced written text impacts the ongoing writing process, as it must be integrated with the newly created text. Long-term memory serves as a repository of knowledge about the subject matter and the intended audience, which can reside in external resources like books or within the writer's mind. Finally, the writing process can be delineated into three stages: planning, translating, and reviewing (Flower and Hayes 1981). During the planning stage, writers construct an internal representation of the knowledge that will inform their writing. Generating ideas, organizing thoughts, and setting goals are key aspects of this stage. The information generated during planning may be represented using various symbol systems beyond language, such as imagery or kinesthetic sensations (Flower and Hayes 1981). The translating stage involves the act of transforming the generated information into written language. The writer must address the specific requirements of linear written language, such as syntax and vocabulary (Flower and Hayes 1981). The reviewing stage comprises two sub-processes: evaluation and revision. According to Flower and Hayes (Flower and Hayes 1981), reviewing can be a conscious process in which writers choose to review their work either as a springboard for further translation or as a systematic evaluation and/or revision of the text. New cycles of planning and translating can then commence. Both sub-processes can interrupt other stages and occur at any point during the act of writing (Flower and Hayes 1981). The cognitive writing model is continuously improved as its usage becomes more widespread. It is divided into various stages that focus on the complexity of achieving the intended goals, which drive the writing process forward. Writing has been recognized as a valuable tool for learning, as it encompasses both the act of writing itself and the resulting written product. This enables writers to engage in continuous reflection on the ideas they aim to convey (Emig 1977). Through the exploration of evolving objectives, researchers in the field of writing have gained insights into why authors can acquire knowledge through their writing (Scardamalia and Bereiter 1987).

Writing Support Systems to Foster Human Cognitive Writing Processes

Writing support systems also referred to as writing assistants, are IS systems designed to assist writers throughout the process of writing. These programs employ artificial intelligence technology to provide various forms of support, ranging from basic grammar checking to helping writers master the intricacies of language and create more engaging content (Ippolito et al. 2022; Karyuatry 2018). The advancements in technology have significantly expanded the capabilities of these writing support systems, presenting new opportunities to aid authors in their writing endeavors (Bommasani et al. 2021). These systems hold the potential to assist writers in real-world, high-impact domains, offering valuable support and enabling the generation of coherent and persuasive text across a wide range of subjects and disciplines (Gero et al. 2022). Following the process theory of writing, writing support systems can support writers at different stages: planning, translating, and revising (Flower and Hayes 1981; Gero et al. 2022). In the planning phase, systems can be identified that follow the *representational guidance approach (Toth et al. 2002)* and support the writers with graphs and diagrams (Hodges 2017). Examples include systems that assist students with planning texts in law (Pinkwart et al. 2009) or help students write asynchronous discussions (Nussbaum et al. 2007). Another example is StoryAssembler which supports narrative writing, due to a dynamic planner system that could assemble choice-based hyperfiction, controlled by a list of design constraints, as opposed to explicitly linked nodes (Garbe et al. 2019). In addition to planning, some systems support the writing itself that support the writing itself, helping writers to translate their ideas into text. This category mainly includes systems that either show the user how to improve his writing or give suggestions on how to formulate it. The Creative Help system helps with creative writing by automatically suggesting new sentences in a story (Roemmele and Gordon 2018). Another example can be found in the literature that supports writing code. The Bing Developer Assistant (BDA) system gives the user suggestions for lines of code during programming by recommending sample API code from public software repositories (Zhang et al. 2016). Other systems focus mainly on the review phase in supporting the writing process. For example, the ELLA system gives students an overview of their cognitive and emotional empathy in a feedback scenario via a dashboard and individual feedback (Wambsganss 2021). In the field of argumentation learning, there are different systems that review students' argumentation skills and work with dashboards and highlighting, among others (Afrin et al. 2021; Wambsganss, Niklaus, et al. 2020).

Existing Classifications of Writing Support Systems

The existing literature on structured design approaches for various writing tools is scarce. However, there are a few notable studies that have explored related areas. Strobl et al. (2019) conducted a review focused on digital support for academic writing. Their study examined the current state of technology and pedagogies used to enhance academic writing and improve the quality of academic publications. The research explored different digital tools and approaches, assessing their effectiveness in supporting the writing process and producing high-quality academic work. Notably, the study primarily emphasized the pedagogical aspect, with limited examination of the technological aspect. Additionally, the review focused solely on secondary school instruction in the United States, making it challenging to generalize the findings to other user groups. Thus, the assumptions made in this study may not directly apply to other contexts. Another relevant work was conducted by Frich et al. (2019), which investigated the landscape of tools available for supporting creative activities. The study identified the characteristics of these tools, the contexts in which they are used, and the types of creativity they support. While this research provided an overview of the key characteristics of creative support tools, design approaches specifically tailored to writing support systems were only briefly considered. The study primarily focused on graphic designers or photographers, with the writing process considered only as a small component of the broader creative process. It is worth noting that both the Strobl et al. (2019) and Frich et al. (2019) studies were conducted in 2019, and since then, newer technologies have emerged, opening new possibilities that have yet to be summarized and structured in the literature. Gero et al. (2022) proposed a design space for writing tools, contributing valuable insights into deriving design approaches for writing support systems. However, their work did not explicitly consider the user types and perceptions. Additionally, they did not explore the specificities of commercial or open-source writing support systems. This gap in the research suggests a need for further investigation to address these aspects. Both the user types and perceptions are crucial factors in developing a meaningful and effective design guide for writing support systems. IS research can especially contribute to these perspectives by investigating the design and development of writing support systems from an interdisciplinary research perspective. In our paper, we use the sociotechnical systems perspective (Bostrom and Heinen 1977) to derive dimensions and characteristics for the design and analysis of writing support systems in humans' cognitive writing processes. Although this perspective and resulting taxonomy are very promising for IS research and practice, to the best of our knowledge, we are among the first to collect design elements of writing support systems.

Methodology

To address the structuration of design dimensions and characteristics of writing support systems systematically, we adopt the procedure for developing a taxonomy from Nickerson et al. (2013), as this has already been used in IS research and has been used to classify several taxonomies (Weber et al. 2021; Zierau et al. 2020). The use of classifications is valuable for both researchers and practitioners as it allows for the organization of complex domains, which is especially crucial in emerging fields like writing support systems. By employing a systematic classification approach, we can coherently reveal the relationships between the various design elements of writing support systems. This process also provides valuable insights into the underlying theoretical foundations. Taxonomies, therefore, play a crucial role in advancing theoretical knowledge (Bailey 1994). Moreover, taxonomies not only offer descriptive and prescriptive value but can also contribute to the advancement of theoretical understanding. This is exemplified by our conceptualization aimed at examining how the design elements of writing support systems influence the outcome variables of writing support systems used in different process steps of the writing process. Consequently, we develop a taxonomy through a four-phase process, as seen in Table 1.

Research Phases	Method	Activities	Sources	Outcome
1. Taxonomy database creation	Systematic literature review (Vom Brocke et al. 2015; Webster and Watson 2002)	1. Literature search in fields of information systems, computer science, and linguistics 2. Analysis of the literature on cognitive writing processes, writing assistance, and outcome variables	Literature of writing support systems	Database of 86 relevant papers for the development of a taxonomy for writing support systems
2. Taxonomy development	Development of the taxonomy for writing support systems (Nickerson et al. 2013)	1. Defining characteristics 2. Iterative taxonomy development until requirements are fulfilled	Classification of writing support systems, Database on writing support systems	Taxonomy with 11 dimensions and 49 characteristics
3. Taxonomy evaluation	Evaluation of the taxonomy (Szopinski et al. 2019)	1. Evaluation of dimensions and characteristics with seven interviewees with domain expertise based on different criteria	Semi-structured interviews with seven interviewees with domain expertise (Rubin and Chisnell 2008)	Evaluated taxonomy by robustness, conciseness, comprehensiveness, and expandability
4. Taxonomy application	Cluster analysis (Kaufman and Rousseeuw 2009)	Cluster analysis to identify patterns of writing support systems characteristics and archetypes	Writing support systems literature emerging from Phase 1	Three distinct clusters of applications and archetypes (A1-A5)

Table 1. Summary of the Four Phases of our Research.

Phase 1: Database Creation Through a Systematic Literature Review

To examine the existing literature on writing support systems, we conducted an extensive systematic literature review based on the principles outlined by Webster and Watson (2002). We used different techniques to conduct the literature review, such as searching relevant journals, keyword searching in databases, and forward and backward searching. In the following, we present these to ensure a high level of transparency and reproducibility of our research.

Search String	Selection Steps				
((automat* OR digital OR computer* OR assist* OR corrective) AND (writing OR feedback OR grammar) AND (technology OR system OR assessment OR tool OR assistance OR support OR evaluation))	Total hits EN	Dupli cates	Hits without duplicates	Relevant after examining	Relevant paper after deeper analysis (backward/forward search)
IEEE Xplore	103	0	103	13	11
ProQuest	404	21	383	54	49
ACM Digital, Library	15	0	14	2	2
Science Direct	134	18	116	19	12
AIS eLibrary	4	0	0	4	3
ArXiv	58	0	58	15	9
Sum:	718	39	674	107	86

Table 2. Overview of Database Hits.

Selection of Search String: We began our examination of writing support systems by exploring the technical system term itself. To gather relevant insights, we reviewed the current literature, including the related work previously mentioned by Strobl et al. (2019), Frich et al. (2019) and Gero et al. (2022). Many of the keywords used are made up of three words that can be generated by the following string: ((automat* OR digital OR computer* OR assist* OR corrective) AND (writing OR feedback OR grammar) AND (technology OR system OR assessment OR tool OR assistance OR support OR evaluation)). We also considered all possible variations and endings of these words, such as singular or plural, as well as other grammatical combinations. We have identified three main science domains in which writing support systems are being researched. These are *computer science*, *linguistics,* and *information systems*. Table 2 summarizes the database hits and the relevant papers.

Selection of Papers: The database search with the selected search string resulted in a total of 718 hits. In the first step, we removed 39 identified duplicates, after which 674 papers remained. In the second step, we sorted out papers that were not relevant to us. Only papers related to any type of writing support system and providing information on primary outcomes from writing support systems used, as the central focus concept and unit of analysis of the papers, were considered. Additionally, only papers on writing support systems that explicitly address writing tasks from the perspective of writing as a cognitive task were considered so that the scope of writing support systems could be as narrow as possible. Thus, the search in the databases and the subsequent selection resulted in 107 papers that we selected for a deeper analysis. We used these 107 papers as a starting point for further forward and backward research and identified 8 additional papers. In total, we thus indicated 86 relevant papers (Table 2). 43 were sorted out during deep analysis.

Analysis of Papers: An abductive approach was employed to analyze the 86 relevant papers from a concept-centered perspective. To aggregate the findings on writing support systems to foster cognitive writing processes, we developed a coding list. Firstly, we identified design elements of writing support systems, namely people (user), task, technology, and structure, based on a process perspective of writing with a sociotechnical system view (Bostrom et al. 2009; Flower and Hayes 1981). This iterative process involved three researchers, conducting multiple coding rounds. In the first round, two of the researchers independently coded the initial set of 30 selected articles. Each paper contributed to the growing list of descriptions and variables for the design elements. The researchers then discussed their findings independently, resolving any discrepancies with the assistance of a third researcher. This iterative process continued until all the papers were coded, resulting in the inclusion of new variables and descriptions along the way. During the coding process, some variables were found to be identical, requiring no further discussion. However, certain variables necessitated deeper consideration. Both coders engaged in discussions for variables that were not initially identified until consistent variables could be established. Following this, the original subset of 30 items was re-examined. In subsequent iterations, the remaining articles were independently coded by two researchers, who increased the frequency of meetings with the third researcher to discuss intermediate results. Additionally, various outcome variables related to writing support systems use were coded and appended to the growing list of variables and descriptions. The researchers then convened to review and discuss the obtained results. If discrepancies emerged, a third researcher was consulted to resolve any differences. This iterative process led to the inclusion of new variables and descriptions in each iteration until all the papers were successfully coded.

Phase 3: Evaluation of the Taxonomy

To assess the quality of our taxonomy, we employed semi-structured interviews following the taxonomy evaluation guidelines proposed by Szopinski et al. 2019. These guidelines consider criteria recommended by researchers to ensure the taxonomy's quality, including conciseness, robustness, comprehensibility, extensibility, and explanatory power (Nickerson et al. 2013). Conciseness evaluates whether the number of dimensions is reasonable and if they appear overwhelming or confusing. Robustness examines the differentiation of dimensions and characteristics within the taxonomy. Comprehensiveness gauges the taxonomy's ability to classify all objects pertaining to a specific phenomenon. Extensibility assesses whether the taxonomy can be easily expanded by adding new dimensions or features. Explanatory power refers to the transparency with which a taxonomy reveals relationships between dimensions and characteristics, thus unveiling previously unknown aspects of the phenomenon. We conducted seven interviews with researchers and systems developers who held proficiency in IS research, research related to writing support systems, practical development of writing support systems, or taxonomy development. Based on the expertise of the interviewees, we would like to evaluate and extend the taxonomy and determine whether it is applicable in practice and research. More information on the profession and expertise of the interviewees can be found in Appendix A. During the period of March to April 2023, we performed semi-structured interviews using a video communication platform, spanning from a minimum duration of 17 minutes to the most extended period of 40 minutes. The interviews were recorded and saved using the video communication platform. Our interview guide comprised 14 open-ended questions, considering the five quality criteria mentioned earlier to evaluate taxonomies (Nickerson et al. 2013). Before the interviews took place, we furnished the interviewees with the most current version of the taxonomy. This enabled them to jot down notes, offer feedback, and analyze areas that could be enhanced. During the interviews, the participants were provided the opportunity to evaluate the taxonomy's quality standards, namely conciseness, robustness, comprehensibility, extensibility, and explanatory power, as per the guidelines outlined in Nickerson et al. 2013. They were also tasked with addressing the questions presented and elucidating the degree to which the taxonomy required augmentation with additional dimensions and characteristics. Upon the conclusion of the interviews, a comprehensive summary discussion encompassed all the key points that had been covered. Based on the conducted interviews, we found that the interviewees generally rated the conciseness of the taxonomy positively. The classification of dimensions based on the sociotechnical system view was perceived as clear and understandable. Most of the interviewees also expressed clarity regarding the individual characteristics. We incorporated a few suggested changes while ensuring that the characteristics remained concise and non-overwhelming. Most dimensions and characteristics were considered robust and had no overlap or imprecision. However, overlaps did occur in the *User* dimension, which we resolved together with the interview partners. The taxonomy was deemed comprehensive enough to describe design elements within the context of a writing process. The interviewees also confirmed the extensibility of the taxonomy, which makes future expansion of dimensions and characteristics possible, as technical expansion will also change the design of writing support systems in the future. That the taxonomy is extensible also became clear during the interviews, as the interviewees mentioned new dimensions or characteristics that could be included in the taxonomy, e. g., Application Area (see Figure 1). Furthermore, the interviewees acknowledged that the relationships between different dimensions and characteristics were transparent, thus providing new insights for the design of writing support systems.

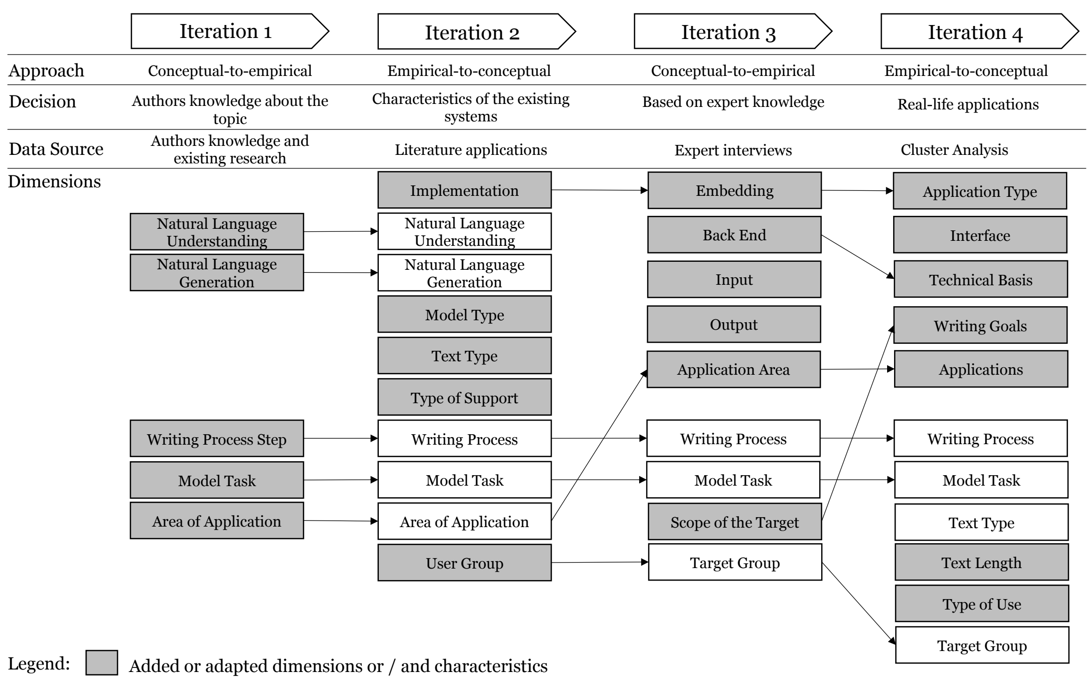

Figure 1. Taxonomy Development Process (Kundisch 2022; Nickerson et al. 2013).

Phase 4: Application of the Taxonomy

In the final phase of our study, we conducted a hierarchical cluster analysis using an agglomerative clustering method, based on our taxonomy and the literature search conducted in phase 1. This approach facilitated the identification of similarities among concepts and their organization into distinct clusters and has been used before in IS research (Wambsganss et al. 2021; Zierau et al. 2020). For clustering, we used the characteristics that emerged from our taxonomy and formed a binary data matrix based on the characteristics. The matrix contains all the papers we identified during our literature search (see Phase 1). The agglomerative clustering process commenced by assigning each concept to an individual cluster.

Subsequently, clusters were merged based on their similarity, gradually forming larger clusters until all concepts were grouped into a single cluster. Throughout this merging process, we utilized Ward's criterion to calculate the Euclidean distance between each cluster (Ward 1963). This distance measurement allowed us to assess the similarity between concepts and ensured that clusters were formed based on the most significant and relevant features of the analyzed papers. The hierarchical nature of our clustering method provided us with both a broad overview and a detailed breakdown of the relationships between concepts. By examining the cluster dendrogram, we were able to identify patterns and correlations within the analyzed papers, while also identifying potential gaps or areas for further investigation (Kaufman and Rousseeuw 2009).

Taxonomy of Intelligent Writing Support Systems

In this section, we present the preliminary version of our taxonomy, which has undergone four iterations and been refined based on feedback from semi-structured interviews conducted in a semi-structured format (Rubin and Chisnell 2008). Our taxonomy incorporates design elements identified as central to the representation of writing support systems, as supported by the literature reviewed. We outline the various dimensions and characteristics in Table 3. The perspectives of the dimensions are oriented to the sociotechnical view of Bolstrom and Heinen 1977 and indicate typical dimensions of design elements of writing support systems. We structure the taxonomy in four perspectives (technology, task/structure, and user), with eleven corresponding dimensions and several characteristics. Each dimension consists of different characteristics, independent of the other dimensions' characteristics.

Technology: Based on our analysis, the dimension of *Technology* can be subdivided into the following three sub-dimension *Application Type*, *Interface,* and *Technical Basis*. *Application Type* describes the environment in which the writing support system is presented to the user, also known as the front end. Our classification builds on previous research and is divided into *Desktop Applications* and *Web-Based Applications* (Strobl et al. 2019). *Desktop Applications* are installed and run on a user's local computer. Users can access the system through a graphical user interface and can use it offline (Han et al. 2020). *Web-Based Applications* are accessed through a web browser and are typically hosted on a remote server (Fahmi and Cahyono 2021). Users can access the system from any device with an internet connection and can collaborate with others in real-time. Inspired by research in the field of AI-based information systems, we have added the characteristics *Mobile Application* (Imran 2022) and *Plugins and Extensions* (Zhang et al. 2016). *Mobile Applications* are designed to run on smartphones and tablets. Users can access the system through a mobile app and can use it on the go. *Plugins and Extensions* are integrated into other software applications, such as word processors or web browsers. Users can access the system through the interface of the host application and can use it to augment the functionality of the host application. Most of the modern systems we examined can be accessed via the browser (Wambsganss 2021), thus they are *Web-Based Applications*. The *Interface* dimension shows how a writing support system interface can be presented while illustrating the extent to which a writing support system has visual features (Afrin et al. 2021). Verbert et al. (2013) stated that writing systems aim to enhance user awareness of relevant and important information using visualizations and overviews. During our research, we identified five different manifestations of writing support system. The interface of a writing support system can be *Text-Based, Voice-Based, Graphical, Multimodal, Adaptive*. In the dimension *Technical Basis* we have classified the systems used in the back end according to three characteristics: *Rules-Based* writing support system use predefined rules and patterns to identify and correct errors and provide suggestions for improving the writing support systems (Liu et al. 2014). These rules are based on linguistic and grammatical principles, such as spelling and grammar rules, syntactical structures, and stylistic conventions. *Rules-Based* writing support systems typically have a limited scope of functionality and are less flexible and adaptive than *Machine Learning (ML)-Based* writing support systems (Liu et al. 2014). *ML-Based* writing support system use algorithms that learn from large amounts of data to identify patterns and make predictions about text quality and content (Makarenkov et al. 2019). These algorithms are based on neural network models that can recognize and generate natural language, and they enable the writing support system to provide more sophisticated and nuanced feedback on writing than the *Rules-Based* writing support system (Makarenkov et al. 2019). *ML-Based* writing support systems are generally more flexible and adaptable than *Rules-Based* writing support systems can provide personalized feedback based on different user needs and contexts (Gorinski et al. 2019). The third characteristic is *Generative-AI-Based*. As their name implies, *Generative-AI-Based* systems can synthesize content (Louie et al. 2020). Mostly driven by LLM such as GPT3 or

ChatGPT, *Generative-AI-Based* systems' capacity to carry out remarkably complex tasks is one step higher compared to *Rules-Based* and *ML-Based* systems (Baidoo-Anu and Owusu Ansah 2023).

Dimensions		Characteristics					
Technology	Application Type	Desktop Applications	Web-Based Applications	Mobile Applications	Plugins and Extensions	Mixed	
	Interface	Text-Based	Voice-Based	Graphical	Multimodal	Adaptive	
	Technical Basis	Rule-Based	Machine Learning-Based	Generative-AI-Based			
Task / Structure	Writing Goals	Fuzzy defined *(almost anything could be helpful, e. g., creative writing)*	Moderately defined. *(moderate variety in "right" answers, e. g., argumentation)*	Specific *(few "right" answers, e. g., Grammar feedback)*			
	Applications	Education	Scientific Writing	Administration	Creativity	Others	
	Writing Process	Planning *(generating ideas, organizing)*	Writing *(transcribing, translating)*	Reviewing *(evaluating and revising)*	More than one Process		
	Model Task	Grammar and Spell Check	Style and Quality Check	Translation	Text Prediction	Text Generation	Writing Strategies
	Text Type	Informative *(e. g., reference work)*	Expressive *(e. g., poem)*	Operative *(e. g., advertisement)*			
	Text Length	Micro-Text *(e. g., headings, slogans)*	Short Text *(e. g., emails, brief notes)*	Medium Text *(e. g., blog posts, news articles, essays)*	Long Text *(e. g., novels, biographies)*		
User	Type of Use	Co-Creation	Review	Collaborative Editing	Individual Use		
	Target Group	Learner	Researcher	Creative User	Technical User	Journalists	User with health conditions or impairments

Table 3. Taxonomy of Intelligent Writing Support Systems.

Task / Structure: The dimension Task/Structure is further divided into the six sub-dimensions *Scope of the Target, Applications, Writing Process, Model Task, Text Type, Text Length*. Based on the assumption that a target can be of varying scope, we have divided the *Scope of the Target* into three categories (Gero et al. 2022). The scope of the writing goal gives us a measure of how particular the support must be to achieve the goal. A *Fuzzy* defined goal can have a lot of solutions. Almost anything could be helpful, like when describing a newly introduced fictional character. A *Moderately defined goal has a* variety of right answers, and the support of a *Highly constrained goal* must be very specific, with few right answers, such as writing a technical definition. Our *Applications* dimension delineates five distinct areas of application, as identified through our analysis of the research papers. Firstly, writing support systems that fall into the *Education* context are designed to be used in educational settings such as schools or universities (Wambsganss, Söllner, et al. 2020). These systems are often customized to help students improve their writing skills and attain academic. Secondly, applications in the *Scientific Writing* context include writing support systems that are specifically tailored for the use in the academic world (Strobl et al. 2019). Researchers, scholars, or other professionals who require high-quality writing that meets specific standards may utilize these systems. Thirdly, writing support systems that fall into the *Administration* context are intended for use in business settings (e. g., Hui et al. 2018). Professionals who need to create reports, proposals, or other types of business communication may use these systems. Fourthly, the *Creativity* context encompasses writing support systems that are designed to facilitate the creative writing process (Clark et al. 2018). These systems may inspire users to experiment with various writing styles or genres and offer prompts or other forms of motivation. Lastly, some writing support systems may fall under the *Other* category. These systems are versatile and flexible, suitable for both personal and professional use, and offer a variety of features and functionalities to meet different user needs. An example of such a system is Grammarly (Karyuatry 2018). The dimension *Writing Process* shows writing phases in which writing support systems can support (Flower and Hayes 1981). During the *Planning* Stage, writing support systems can assist writers with brainstorming, organizing, and outlining their ideas (Hodges 2017). These systems may include tools such as graphic organizers and outlining software that help writers structure their thoughts and ideas. In the *Translating* Stage, writing support systems can help writers translate their broad ideas into more cohesive and structured forms. These systems may include tools such as sentence construction aids, vocabulary suggestions, content analysis, and automatic summarization (e. g., Ippolito et al. 2022). During the *Reviewing* Stage, writing support systems can help writers identify flaws and revise their work. These systems may include tools such as grammar and spelling checkers, plagiarism checkers, and readability analysis (e. g., Schmidt 2020). Certain writing support systems extend their functionality to encompass multiple processes, addressing various stages of the writing process. These systems might include capabilities like grammar revision, plagiarism detection, as well as tools for brainstorming, organizing, and editing (e.g., Chen and Pan 2022). In the dimension *Model Task different model types are characterized.* The first model task is *Grammar and Spell Check*, which analyzes text for grammatical errors and misspelled words (Bryant et al. 2022). The second model task is *Style and Quality Check*, which assesses the content for writing style, readability, and consistency. This model task assists writers in aligning their text to a particular format and ensuring it is easy to read and understand (Sterman et al. 2020). The third model task is actual *Writing,* which helps writers or translators working on multilingual content. We have added this model task because we have noticed that modern translation programs have many features in common with writing support systems (Huang et al. 2013). *Text Prediction* is the fourth model task that enables writers to predict the words or phrases based on the context, reducing their writing time while increasing efficiency. With this model task, writers can concentrate on creating their content without the burden of searching for the ideal words. The fifth model task is *Text Generation*, which produces new content based on existing text or prompts. This model task is useful for generating reports, summaries, or other written work, making it easier for writers to create content quickly and efficiently (Schneider et al. 2022). Finally, *Writing Strategies* is a model task that helps writers manage their projects, goals, and deadlines. This model task provides workflow management and organization of files, ensuring that writers can stay on top of their work and meet their deadlines (Olson et al. 2017). The dimension *Text Type is based on* three text types proposed by Reiss (1989). The first text type is *Informative*, characterized by the plain communication of facts, opinions, or knowledge, focusing on content. The second text type is *Expressive*, where the language's aesthetic dimension is emphasized, and the form and sender take precedence. The third text type is *Operative*, with the appellative function aimed at inducing specific behavioural responses from the receiver by using dialogic language and focusing on persuasion, as in political speeches or advertisements. Furthermore, texts can be categorized by *Text Length*. We have decided to divide the *Text Lengt*h into 4 text categories for our taxonomy. *Micro-Text* are texts with less than 10 words, such as headlines, slogans, keywords, or social media posts (Khoury et al. 2014). *Short Text* are texts with a length of 10 to a maximum of approx. 100 to 200 words, such as emails or short notes (Liu et al. 2020). *Medium Texts* are texts that contain approx. 100 to a maximum of 1000 words. Blog posts, news articles or essay papers can be mentioned here as examples (Fleckenstein et al. 2020). *Long Texts* are texts with more than 1000[1] words, such as novels, non-fiction books or extensive scientific papers.

User: The dimension *User* is further divided into the two sub-dimensions, *Type of Use* and *Target Group*. *The dimension Type of Use* describes how the writing support system is used. A writing support system can be used to create a document with several people together, therefore the characteristic of *Co-Creation* is included. On the other hand, with *Collaborative Editing* a writing support system can be used to collaboratively edit an existing document. Furthermore, a writing support system can be used to *Review* each other. However, a writing support system can also be used for *Individual Use*. Through our analysis of the papers, we have discerned that writing support systems aim to assist various intended *Target Groups*. This includes pupils, students, teachers, lectors, academics, researchers, authors, writers, managers, employees, programmers, songwriters, novelists, and individuals interested in writing for various purposes. To obtain a better overview, the individual interest groups were further summarized so that the following six target groups can ultimately be described. *Learners* use writing support systems sustainably. This means that the learning aspect is in the foreground (Wambsganss 2021). Writing support systems for *Researchers* provide support in academic writing conventions, publication, managing citations, reference material, organizing complex research data, and drafting research papers (e.g., Hyland 2002). Writing support systems for *Creative User* includes tools for brainstorming, drafting, revising, and tracking progress (Clark et al. 2018). Writing support systems for *Technical User* provides tools for drafting business communication, reports, proposals, writing support for business purposes and support in the programming language. *Journalists* use writing support systems to find relevant content to include in their narratives or

[1] Following the gradation procedure of the other text lengths.

to write in a specific style (Maiden et al. 2018). Lastly the taxonomy shows writing support systems are designed to assist users with health conditions or impairments.

Cluster	Description	Percentage of studies	Archetypes
C1:	Applications in art and literature	34%	A1: Creative writers are supported in the planning phase. A2: Generative text models provide support to creative writers during the planning phase by suggesting text and word choices.
C2:	Applications in economy and research	26%	A3: Researchers receive support in the form of text prediction with a high solution horizon.
C3:	Applications in education	40%	A4: Learners who engage in writing informative texts can receive support in improving their grammar. A5: Learners who engage in writing informative texts can receive assistance in improving both the quality and style of their writing.

Table 4. Identified Writing Support Systems Clusters (C1, C2, C3) and Archetypes (A1-A5).

Clusters of Writing Support Systems Applications

Our objective was to analyze the literature and identify clusters that would aid in interpreting the utilization of specific writing support systems application groups and fill gaps in existing research. We organized the empirical studies into a binary data matrix and rearranged the columns using Ward's algorithm (Ward 1963). By examining the resulting dendrogram, the algorithm successfully differentiated three distinct clusters (C1, C2, C3) in writing support systems. These clusters were mutually exclusive and encompassed all possible application patterns, each characterized by variations in the application area and the writing phase of the writing support systems applications. Building upon the clusters, we proceeded to identify five distinct and more detailed archetypes that exemplified specific manifestations within each cluster. Cluster 1 (C1) comprises 29 out of 86 studies (34%) and predominantly encompasses a writing support system that focuses on creative writing tasks in art and literature. The main reason why these writing support system applications fit together is the focus on expressive texts that require a high level of creativity. Two archetypes can be derived from the creative writing use case, A1 and A2. Archetype 1 shows that writing support systems support creative writing primarily in the planning phase. Archetype 2 shows that the models behind the writing systems primarily generate texts or words, from which it can be deduced that creative writing is primarily supported by text generation. The second cluster of identified studies focuses on writing support systems for use in the business context and research (C2, 22 out of 86). The identified studies are similar in the high-solution horizon given to the users. In both research and business contexts, not every type of input helps writers, but only very specific tools. In the cluster, one archetype can be identified (A3). Writers who primarily write operational texts, i.e., those that need to be persuasive, receive predictive text suggestions. This focus on the writing support systems in this cluster makes sense since texts in the economic field as well as in research, must be convincing. The word suggestions help the writers, while actually writing, to focus on the content, which is most complex. The last cluster describes mainly use cases in the field of education, 40% of the analyzed studies can be classified here (C3, 34 out of 86). In addition to the educational context, the works have in common that the solution horizon is much narrower compared to cluster 2 and that the reviewing phase is addressed. In the last cluster, two archetypes (A3, A4) can be derived. Writers who create informative texts in the educational context are mostly supported in the review phase of writing. They receive support from the system when they revise their work. A3 describes that students receive corrections mainly in terms of their grammar and spelling. This derives mainly from the teaching focus on younger learners, who should be taught spelling and grammar. Archetype 4 delves into the content level of feedback, specifically examining the writing style and the quality of content provided. This archetype focuses on evaluating the depth, coherence, and effectiveness of the written material in terms of both stylistic elements and the substance of the content. It considers factors such as grammar, sentence structure, clarity, logical flow, organization, and the overall impact of the writing. Archetype 5 aims to provide insights into how feedback can be tailored to improve the writing style and enhance the overall quality of the content produced.

Discussion and Research Agenda

In this section, our objective is to propose a preliminary research agenda that outlines potential avenues for future investigations in the field of writing support systems, particularly in IS research. We aim to demonstrate how these research areas can be situated within the dimensions and characteristics of our taxonomy. Drawing upon our literature review, taxonomy, and cluster analysis, we highlight that these identified dimensions offer a distinct perspective for studying writing support systems. This perspective aligns with the theoretical framework of the cognitive writing process (Flower and Hayes 1981), as we apply a sociotechnical viewpoint (Bostrom et al. 2009; Bostrom and Heinen 1977). Specifically, we aim to illustrate the frequency of design characteristics based on the specific characteristics identified within our study sample. By doing so, we can provide valuable insights into the effective utilization of writing support systems. Although recent technological developments could make the design of writing support systems more adaptive, the systems we identified exhibit a more classical design. We could not identify any systems that have incorporated graphical or voice-based interactions into their interface design, although this could lead to new possibilities and interaction forms. Speech enhancements, for example, could help users with disabilities. Writing support system research, as demonstrated by our taxonomy, already encompasses a wide range of users and audiences. However, there is a notable gap in research concerning writing support systems specifically designed for individuals with disabilities, such as attention deficits, dyslexia, or physical limitations. This area holds significant potential for important support values and necessitates special design requirements that should be considered. Although most research supports distinct writing phases, the measured impact of each support interaction needs to be improved. Only 65% of the identified papers show outcome variables, with most focusing on system perception and only the least showing improvement in writing support. This suggests further potential for research between designs and resulting outcome variables. The effects of certain design combinations would be interesting to determine to provide further insights into the design of writing support systems. Most writing support systems are used individually, but due to the progress in location and time-independent work, systems that consider collaborative writing should also be analyzed. Our analysis specifically focused on examining 2% of research papers related to the subject at hand. As a result, we identified several potential avenues for further exploration and investigation in this area. With advancements in technology, an increasing number of researchers are utilizing generative AI as the backend for writing support systems. Our analysis reveals that 32% of the papers we examined already incorporate generative AI in their backend. Considering the ongoing development of LLM, it is reasonable to expect a further rise in the use of generative AI in the future. Therefore, the development of systematic design approaches for writing support systems that leverage generative AI would prove valuable. Given the emphasis on generative AI and LLM in development, it is imperative to address ethical considerations alongside these endeavors. These concerns encompass the potential reliance on technology, where an excessive reliance on writing support systems might lead users to neglect their writing abilities or become overly dependent on automated support. Additionally, there is apprehension regarding the reproduction of unintended biases or discrimination within writing support systems, which could arise from the favoring of specific speech patterns or biased evaluation based on users' demographic characteristics. Furthermore, ethical concerns also arise from the automatic generation of texts. These include areas such as the use of bots and personalized advertising, which can now be designed to appeal directly to an individual's preferences. Furthermore, spam emails can be generated, flooding in boxes with unwanted and potentially harmful content. In addition, trolls on social media platforms are using generative AI to amplify their disruptive activities. The potential manipulation of speech to persuade and influence raises important ethical considerations that deserve thorough investigation.

Dimensions	Research Opportunities	Research Questions
Interfaces	• Writing support systems based on alternative interfaces	• What influence have alternative interfaces like graphical or voice-based interfaces on the interaction with writing support systems?
Target Group	• Writing support systems that support users with certain health conditions or impairments	• How should writing support systems be designed to consider different limitations such as attention disorders, physical limitations or problems in coordination or dyslexia?
Writing Phases	• The connection between the support of different writing phases and the output from the support	• To which outcome variables does the support of different writing phases lead?

	• The combination of the support in different writing phases and the possible outcome from the support	• Which combination of support for the different writing phases is most effective for which outcome?
User Type	• Support for collaborative writing processes	• How can collaborative writing processes be effectively supported by writing support systems?
Technical Basis	• Use of LLM in writing support systems	• How can LLM be effectively used in Writing Support Systems? • What are the design requirements for systems using LLM?

Table 5. Initial Research Agenda on Writing Support Systems Based on our Taxonomy.

Contributions and Limitations

Our work makes both theoretical and practical contributions to the field of writing support systems. Theoretically, we offer the following contributions. Firstly, we amalgamate existing literature, encompassing literature reviews on writing support systems, by developing a new taxonomy that goes beyond the current classifications, structurings, and groupings of design features of writing support from a cognitive process view (Flower and Hayes 1981) and a sociotechnological view (Bostrom et al. 2009; Bostrom and Heinen 1977). By combining the dimensions and features of our taxonomy, IS researchers and practitioners will be able to determine in the future which design features influence which writing phases and how. This paves the way for future research, allowing for more expansive exploration and in-depth insights into the application, embedding, and design of writing support systems. Secondly, we identify and classify new dimensions and features beyond the technical perspective of writing support systems. Third, the different features are categorized and clustered into three different groups (C1, C2, C3) and five corresponding archetypes (A1-A5). These clusters and archetypes will help researchers and practitioners gain an overview of existing research on writing support systems and find gaps in the literature. We hope that our research findings will provide a starting point for further development of guidelines or frameworks for identifying the requirements of writing support systems. The increasing development of LLM and the utilization of adaptive feedback through NLP or ML techniques have sparked the need for research in the field of writing support systems. To facilitate such research, it is crucial to establish a robust classification system and theoretical framework. This paper aims to fulfill this need by introducing our taxonomy, demonstrating its application through cluster analysis, and presenting a comprehensive research agenda (see Table 5). By offering our taxonomy, we enhance the knowledge base regarding design features for writing support systems. Through the utilization of cluster analysis, we gain valuable insights into the classification and organization of these systems. Additionally, we provide researchers with a broader perspective on the study of writing support systems, laying the foundation for further exploration and extension of the taxonomy through future investigations. In doing so, we contribute to the development of the emerging research field of intelligent writing support systems, which is still in its early stages. Our work not only contributes to the advancement of writing support systems but also serves as a valuable resource for researchers seeking to delve into this domain. By establishing a solid theoretical understanding and research agenda, we foster further growth and exploration within the field, promoting the development of innovative and effective writing support systems. In addition to the theoretical contributions of our research, we also offer practical implications that can be derived from our work. The systematic classification of writing support system applications presented in our study empowers IS researchers and practitioners to develop diverse technological designs for writing support systems and evaluate their effectiveness. By leveraging our taxonomy, IS designers can now identify and combine different features to create various types of writing support designs, considering factors such as the target audience or the desired text type. This practical contribution facilitates the development of customized and targeted writing support systems that align with the unique needs and goals of users. It enables IS designers to make informed decisions in the design and implementation process, leading to more effective and user-centric writing support interventions.

With respect to our work, some limitations must be mentioned. Our taxonomy was developed during a systematic literature analysis, which means that we only considered systems about which scientific papers have been written. Systems that have been used in practice, but have not received any scientific attention, have thus been neglected. In addition, it is important to note that our taxonomy may not fully address the various ethical considerations associated with the use of writing support systems. However, it is crucial to recognize that this limitation stems more from the current state of the literature in this area rather than a flaw in our research methodology. We acknowledge this gap and have extensively discussed it in the *Discussion* section, outlining the need for further exploration and examination of ethical implications in the context of writing support systems. Moreover, our taxonomy was formulated according to a particular perspective on sociotechnical systems within the field of IS (Bostrom and Heinen 1977). It's worth noting that adopting an alternative viewpoint on sociotechnical systems could yield disparate outcomes. The last limitation is that our work only covers a certain time and thus the taxonomy will need to be extended in the future. Especially with the further development of AI and LLM, future extensions could be useful.

Conclusion

In summary, our findings offer valuable insights for both research and application of writing support systems, giving researchers a concise understanding of their design. These insights hold relevance in improving support for various use cases and stages of the writing process. Our research process involved four iterations of literature review, combining both conceptual analyses based on existing writing support systems classification literature and empirical analysis of 86 identified articles on writing support systems through a systematic literature review in the fields of *Computer Science*, *Linguistics,* and *Information Systems*. We further validated our taxonomy through consultation with seven interviewees with domain expertise and conducted a cluster analysis, identifying three clusters and five archetypes. With our taxonomy and the derived clusters, we offer potential research directions for designing and implementing writing support systems. Researchers and practitioners can use the results of our study to identify specific design features of writing support systems in the future and to further investigate the effects of writing support systems on different stages of writing. By systematizing and synthesizing existing research, our study contributes to a deeper understanding of writing support systems and provides practical guidance for researchers and practitioners in the field.

Acknowledgement

The results presented in this article were developed in the research project Komp-HI funded by the German Federal Ministry of Education and Research (BMBF, grant 16DHBKI073).

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Appendix

Interview	Function	Expertise
1	Researcher	AI-Supported Human Learning.
2	System Designer / Junior Researcher	Design-oriented research in the field of writing support systems.
3	Researcher	Application of ML.
4	Researcher	AI-Supported Human Learning.
5	Researcher	Design-oriented research in the field of writing support systems.
6	Researcher	Taxonomy Development of Conversational Systems.
7	Researcher	Design-oriented research in the field of skill learning.

Table 6. Researchers and Practitioners Interviewed in the Evaluation of our Taxonomy.