
COMPUTING NUMERICAL IMAGES OF STUDENT WRITING: PERSPECTIVES FROM EDUCATIONAL RESEARCH

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Abstract

With the rapid increase in the number of available digital texts in schools, new methodological approaches to studying writing development in education are now emerging. However, with new methodological approaches follow new epistemological challenges. In this article, I examine some of these challenges and discuss how they affect the role of computational linguistics within the field of educational writing research. The article is structured around three main sections. First, I position computational linguistics within the wider field of educational writing research with particular focus on L1 writing and K12 education. Second, I discuss to what extent methods from computational linguistics can provide us with new insights into different aspects of educational writing. Third, I discuss the potential of the concept of affordance to bridge between technology-centered and human-centered methodological approaches, and I relate this idea to recent theoretical developments in the digital humanities. Based on this discussion, I conclude the article with suggestions for possible directions in future writing research.

Keywords: Computational linguistics, digital methods, writing research, learner corpora, L1 writing, education

1. Introduction

Computational linguistics (CL) is by no means a new research field. It traces back to the very early days of computing in the 1940s, and it has since had great impact within fields such as machine translation and artificial intelligence (Hirst, 2013). It is, however, with the advent of text corpora and corpus linguistics in the 1960s and 1970s (McEnery & Hardie, 2013) and later with the massive digital transformation of our communicative practices in the 21st century (Baron, 2009) that CL and its related digital methods for processing language have become an important part of many humanistic and social science disciplines. Within educational

science, the pervasive digitization of educational practices and the consequent stream of digital data have resulted in an increasingly vast number of student texts now being available in digital formats for researchers. Unlike many other data types generated by digital media (Manovich, 2001, 2020), written texts still hold many traditional dispositions (e.g., linearity) that make them easier to process computationally. This means that it, at least from a technical perspective, has become easier to build large corpora of texts written by students across all levels of the educational system. As a result, new innovative methodological approaches for studying student writing are emerging, especially from within the field of natural language processing (Eisenstein, 2019), and new sub disciplines within educational science, such as learning analytics (Siemens, 2013) and writing analytics (Moxley et al., 2017), are now seeing the light of day.

With new methodological approaches follow new epistemological challenges, and the ‘computational turn’ (Berry, 2011) within humanities and social science studies has attracted harsh critique, also from within educational science (see e.g. Perelman, 2012; Selwyn, 2015, 2019). The critique centers around two main ideas. One, that computational analyses are considered somewhat incompatible with the epistemic pluralism and interpretive processes typically associated with humanistic studies (see e.g. Da, 2019; Fish, 2018a, 2018b). Two, that digital research is often tinged with a touch of technocentrism, in the sense that it is driven more by the possibilities provided by new types of digital data and software tools than by disciplinary agendas (see e.g. Anderson, 2008; van Es et al., 2018; Wise & Shaffer, 2015). These objections are interesting because they touch upon an important question, namely what it actually means to study texts and writing on the basis of an integration of humanistic and computational approaches.

Responding to these critiques, Gavin (2020) investigates the following question: “What relation exists between the textual domain and its numerical image?” (p.4). Gavin’s investigation of this question is set within the context of literary studies. He argues that numerical images of texts, which is Gavin’s term for the statistical results of computational text analyses, do not merely decompose and reduce textual sophistication, rather they reconfigure texts and relate them to other texts within the corpus in ways that are still sensitive to context and subtle semantic nuances. In

this sense, Gavin elaborates on Moretti's (2000, 2013) idea of 'distant reading', which, as the name suggests, describes computational text analysis as an activity in which distance is an epistemological condition; i.e. it allows researchers to examine units and patterns otherwise indiscernible when close reading texts 'manually', units and patterns that are either much smaller (syntax, morphology, tropes, etc.) or much larger (register, style, genre, etc.) than the text itself.

In computational studies of writing in educational contexts, which is the main topic of this article, the question of how numerical images relate to different objects of study (theme, genre, register, etc.) is even more complex. This complexity is first and foremost due to the normative nature of education, where different modes of evaluation, among other important elements, are constitutive of educational practices (Bernstein, 1990). This constitution means that not only must the numerical images generated by computational analyses represent the text itself, but they must also act as a performance proxy of other more pedagogically inherent phenomena, such as student competence or school discourse. This means a further inflation of the cross-disciplinarity of CL in the sense that computing and linguistics must also adhere to principles from other disciplines such as cognitive psychology and psychometrics.

In this article, I examine the role of CL within the field of educational writing research. To do so, I first position computational studies of writing within the broader field of writing research in education. I then discuss to what extent CL methods can provide us with new insights into different aspects of educational writing. This discussion is based partly on a model of an educational writing situation in which I elaborate on a four-part language model proposed by Stubbs (2007) and partly on Carter's (2007) metagenres for educational writing. Finally, I discuss whether the notion of affordance provides a viable conceptual pathway for CL to bridge between technology-centered and human-centered approaches to studying writing development in education.

2. Educational writing research

Since the introduction of the notion of *multiliteracies* in the seminal work of The New London Group (1996), much theoretical and empirical inquiry within education has examined the new networked communicative practices caused by digital media, with particular emphasis on

multimodality (e.g. Cope & Kalantzis, 2000, 2009; Jewitt, 2006; Lankshear & Knobel, 2003). Drawing on social semiotic ideas first introduced by Halliday (1978), the notion that contemporary communication works by means of many different communicative modes has become dominant, especially pioneered by the work of Kress & van Leeuwen (1996) and Kress (2010). Alongside the focus on multiliteracies, much writing research within the last two decades has focused on the wider sociocultural dimensions of writing (Barton, 1994; Street, 1984, 1995), such as matters of writer identity and writing instruction (Parsons et al., 2020). The result of this focus has been that sociolinguistic and ethnographic approaches have dominated the field. However, forwarded particularly, of course, by the appearance of new digital methods, but also by the fact that written language still remains the main mode of non-verbal communication in both school and everyday life (Biber & Egbert, 2018; Brandt, 2014; Bremholm et al., 2018), we are now slowly seeing a resurgence of written language itself as an important object of study in writing research.

2.1 Corpus-based studies of L1 writing

It has long been common within fields such as second language acquisition (L2) or foreign language teaching to study corpora of learner language. Studies of, for instance, language transfer, specific linguistic features or larger rhetoric constructs are thus seen as key in understanding different stages of interlanguage development or as a basis for instructional decision-making (see e.g. Reppen, 2010; Tracy-Ventura & Paquot, 2020). However, if we look at studies focusing exclusively on L1 writing, the image is less clear. Influenced by, among others, the works of Biber (2006) and Hyland (2004), several L1 studies have focused on different dimensions of language use in higher education, such as register variation, stance or voice. Most of these studies have targeted professional and published academic writing in the form of, for instance, journal articles and textbooks (see e.g. Gray, 2015; Römer et al., 2020) or texts written by university students (see e.g. McNamara et al., 2009). K12ⁱ, on the other hand, is still a relatively understudied context. Two important reasons for this have probably been that texts have been difficult to collect due to a lack of standardized digital infrastructure in schools, and that primary and lower secondary writing is more erroneous and thus complicates pre-processing of textual data as well as the data analysis itself. As a result, corpus-based studies of student texts

from K12 are often based on prompted writing (as opposed to naturally occurring writing) and thus presuppose an intervention-based or experimental research design.

2.2 Diachronic and synchronous approaches

Although overlapping and entangled, K12 studies can for the sake of clarity be divided into two groups: those that adopt a diachronic perspective and those that adopt a synchronous perspective. Diachronic studies are typically longitudinal and often focus on developmental aspects of either different types of writing (narrative, persuasive, argumentative etc.) (see e.g. Beard & Burrell, 2010) or on specific genres (see e.g. Olinghouse & Wilson, 2013). Many of these studies adopt a functionalist linguistic perspective, often originating in Halliday's (2013) systemic functional linguistics. Christie & Derewianka (2010), for instance, studied disciplinary and genre related differences in the writing trajectories of children aged 5-18. Others, such as Troia et al. (2019) and Beers & Nagy (2011), have studied how different word and syntax level variables develop as a function of grade level. A shared feature in these studies is an interest in studying linguistic development in student texts across age levels using either a longitudinal or a cross-sectional design.

Synchronous studies, which likely outnumber diachronic studies, are more focused on immediate differences between texts in a comparative or evaluative perspective. Hardy & Römer's (2013) study of disciplinary differences in upper-level student writing is a good example of this approach. In this study, the authors show how different registers are realized linguistically in student texts and examine how the registers vary according to disciplines. The purpose of synchronous studies is thus not to study how writing develops across time or year levels, but rather to study how texts differ according to synchronous variables (e.g. genre, motivation, writing attitude, or self-efficacy). Another important research area within this approach is writing assessment, particularly automated essay scoring, which is a specific kind of automatic assessment based on NLP and machine learning techniques (Shermis, 2014; Shermis & Burstein, 2013). Studies in this area aim to examine the characteristics of texts with different proficiency scores, which can then be used to automatically assign other texts with a certain score.

3. What is a student text?

Before discussing more directly the potential of CL methods in educational writing research, it is important to consider a couple of rhetorical circumstances that make educational writing very different from other types of writing.

3.1 Student texts as text acts

From a rhetorical perspective, student texts are complex. On the one hand, they are socially situated textual actsⁱⁱ between a student and a teacher within a confined educational context with more or less clear social and textual norms. But, on the other hand, they are also fictional texts addressing fictional readers outside the context of the textual act (Togebly, 2015). This means that the success criteria of student texts do not necessarily follow from the genre, as they would otherwise if we followed, for instance, Swales' (1990) genre definition. For instance, writing a job application in school does not have employment as an actual success criteria; instead, the text has to meet metafunctional success criteria such as adhering textual norms explicated by the teacher or getting a specific grade (Berthelsen, 2021). Of course, this ambiguity in the rhetorical situation manifests itself in different ways in both writing assignments and student texts (Juuhl, 2020; Kvistad & Otnes, 2019; Troelsen, 2018), but the general idea is that the illocutionary force in student texts, i.e. the intended function of an utterance (Searle, 1969), is either suspended or at least to some extent distorted.

This aspect of educational writing is in many ways deeply embedded in the disciplinary structure of schooling. As pointed out by Carter (2007), the textual act of writing in education expresses different kinds of knowing and doing within the disciplines, because the primary purpose of writing within a discipline is learning, and the successful realization of such a purpose is of course related to - but not directly equivalent to - a generic notion of writing competence or text quality. Instead, writing in different subjects relates to different kinds of academic situations that require different ways of expressing knowledge and doing. Therefore, Carter proposes four metagenres for educational writing, which relate to different disciplinary traditions. The first metagenre, *problem-solving*, is related to disciplines originating in the applied and project-oriented sciences. It is a kind of writing aimed at identifying real-world problems, analyzing the

problem using theory, suggesting possible solutions, and evaluating the project according to established criteria. The second metagenre, *empirical inquiry*, is aimed at examining phenomena based on systematic investigations of empirical data. The first two metagenres have relatively generic success criteria known from the sciences (correct use of methods, truth value, practical impact, etc.), which function as communicative ends in themselves. That is, however, not the case with the third metagenre, *research from sources*. According to Carter, a distinguishing feature of the third metagenre is that the value of the textual act is intrinsic to the discipline. It involves learning to write based on other sources, not as an end in itself, but as a means of learning a specific disciplinary kind of knowing. Hence, when students in school are asked to write an analysis of a novel, for instance, the value of the textual act is not primarily about whether they have followed an explicit procedure correctly or whether their analysis is true (as it would be if they were conducting an experiment in biology); it is instead about learning to understand literature from a specific disciplinary perspective. In the fourth metagenre, *performance*, the focus is on the act of performing and specifically on the result (artifact, text, etc.) of such a performance. An example of this is when students are asked to write texts for no other purpose than showing the teacher that they master specific textual norms or writing styles. The four metagenres are summed up in figure 1 below.

As has no doubt become clear, student writing is in many ways a complex compound of rhetorical, social, institutional and disciplinary dimensions. The rhetorical ambiguity is common for most educational writing, but, as displayed by Carter's (2007) metagenres, it manifests itself differently in different disciplines. This obviously has implications for how to conceive student texts as research data, which I will examine in the following section.

Metagenres (Carter, 2007)	Characteristics	Examples of educational writing tasks
Problem-solving	Identifying real-world problems, analyzing problems based on theory, suggesting solutions, evaluating according to established criteria. <u>Success criteria:</u> Correct use of methods and viability of suggested solutions.	STEM reports Social studies papers Project reports
Empirical inquiry	Formulating hypotheses, collecting empirical data, systematically investigating empirical data. <u>Success criteria:</u> Correct use of methods and validity of results.	Biology reports Physics/chemistry reports
Research from sources	Examining phenomena based on established sources, discussing. <u>Success criteria:</u> Adopting and becoming familiar with a specific kind of disciplinary knowing.	Literary analyses Cultural essays Historical essays
Performance	Performing according to specific norms and criteria, the product is evaluated according to different levels of proficiency. <u>Success criteria:</u> Displaying proficiency according to specific disciplinary norms.	Non-academic texts (e.g. journalistic texts and job applications) Essays in foreign language teaching

Table 1: Carter's (2007) metagenres for educational writing

4. Student texts and their numerical images

In the introduction, I presented the idea that the numerical images generated by CL can have multiple referents related to linguistic, cognitive and wider social and cultural dimensions, e.g. discourse, register variation

or individual competence. In the following, I will therefore discuss the potentials and limits of using methods from CL to study different aspects of educational writing. I will first introduce a model representing a reduced graphical configuration of an educational writing situation. I will then consider the individual parts of the model relating each of them to Carter's metagenres and discussing to what extent CL methods can provide new epistemological insights into the individual dimensions.

4.1 Model of an educational writing situation

Educational writing research is an umbrella term for the study of a range of different concepts. Concepts such as school discourse, writing competence, academic voice and adverbial phrases all share the notion that they can be studied by means of text corpora, but they are also distinct from each other and hold distinctly different ontological properties. When studying text corpora we are, on the one hand, studying observable utterances, e.g. words and sentences, that exist as brute facts (Searle, 1995) with physical properties (e.g. as ink marks on a piece of paper or as pixels on a screen), although corpus-based studies of texts can of course not merely be reduced to studying such physical aspects of language. We are, on the other hand, also studying something else, namely the social, structural and cognitive dimensions related to specific instances of language use. Stubbs (2007) thus argues for a pluralist model of language as the basis of corpus studies. Drawing on Tuldava's (1998) original distinctions, Stubbs proposes a four-part model consisting of two overlapping conceptual pairs. The first is between the potential and the actual, i.e. between the prerequisites and constraints of language use (e.g. individual competence or what is possible within the language system) and actual realized language use (e.g. discourse or text), and the second is between process and product, i.e. between the process of producing language (e.g. writing a text) and the linguistic products emerging from these processes (e.g. the text itself). To varying extents, it is possible to study these elements computationally.

To fully understand educational writing, however, I argue that we need a more specialized model. In particular, the concept *potential* needs to be specified not only in terms of grammar and the cognitive capacities of the individual, but just as importantly in terms of the social and pedagogical dimensions that form specific instances of educational writing.

Several studies have, for instance, shown that student writing is highly susceptible to different instructional framings (see e.g. Graham et al., 2012; Graham & Perin, 2007) and to individual variables such as social background (Dunsmuir & Blatchford, 2004) and writing attitude (Graham et al., 2017). In the model below, I therefore distinguish between the *instructional framing* and the *sociocultural framing* of educational writing. Other more specialized and conceptually complex models have of course been developed, such as Flower & Hayes' (1981) cognitive process model or Kern's (2000) contextual literacy model. These models all provide valuable insight into different dimensions of writing. However, for the sake of the arguments made in this section, it is sufficient to provide a minimalist graphical display representing a reduced configuration of an educational writing situation.

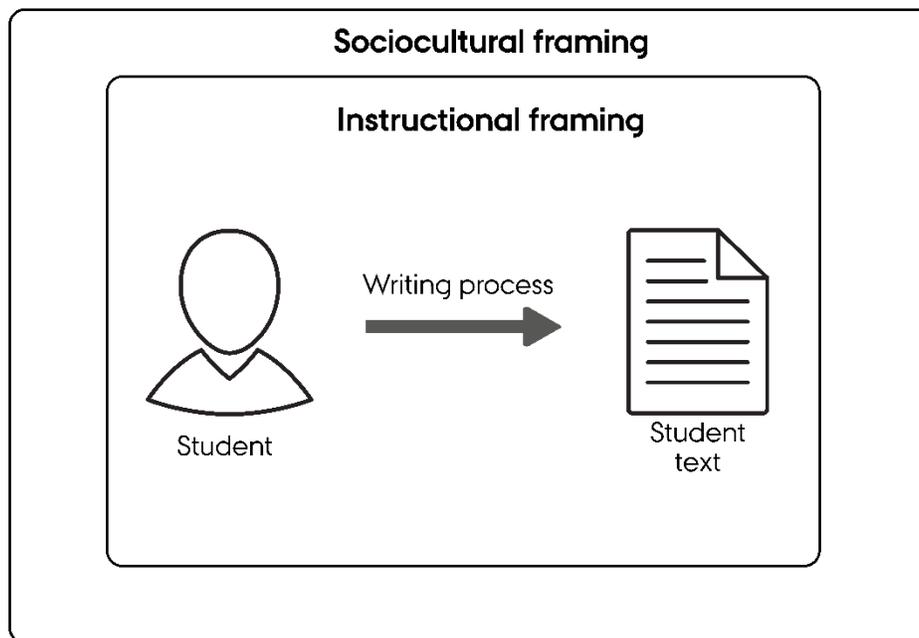


Figure 1: Minimal graphical configuration of an educational writing situation

The center of the model shows the student (i.e. the writer), the writing process and the student text, which mirror Stubbs' (2007) notions of *potential*, *process* and *actual/product* respectively. In this case, the student refers to the cognitive capacities of the individual writer, the writing

process to the process of producing written text, and the student text to the actual physical record of written language. As briefly hinted above, instructional framing refers to the specific instructional designs that form the writing situation, such as the writing task or scaffolding activities, whereas sociocultural framing refers to social variables related to both the individual, such as social background or writing habits, and to wider cultural and institutional aspects, such as school discourse or disciplinary traditions.

4.2 What computational linguistics can and cannot tell us about educational writing

CL deals with linguistic data, often in the form of written texts or transcriptions of spoken language. In the following section, I will discuss to what extent computational analyses of this kind of data can provide us with insights into different aspects of educational writing.

4.2.1 The student

In this context, studying ‘the student’ means to study individual competence. When student texts are used to study individual competence, they are essentially treated as performance data, i.e. as data that represents deliberate student actions relating to qualitatively different levels of proficiency. However, as we have seen in the description of Carter’s metagenres, students display competence in different ways according to different purposes and success criteria in each metagenre. This means that the extent to which these success criteria can be measured computationally varies according to metagenre. An obvious aim in educational writing research is, for example, to study students’ writing competence, either as a generic construct or as a more domain-specific or genre-specific skill (e.g. narrative writing or argumentative writing). This relates directly to Carter’s metagenre *performance* in which the primary success criteria of student text acts are not related to communicative purposes, but rather to displaying mastery of specific linguistic structures and norms. This is of course particularly evident in foreign language teaching, where students often write to practice specific linguistic structures and styles, but it also applies to L1 writing, which is often assessed on the basis of formal criteria, such as correctness or style.

An important research area aimed at measuring the individual competence of students by using CL methods is that of writing assessment. In recent years, the application of CL methods has been particularly evident within the field of automated essay scoring, in which researchers try to develop software tools that can automatically analyze features in texts and on that basis assign similar texts with a certain score (Correnti et al., 2020; Shermis, 2014). The theoretical underpinnings of many of these studies are often located in probabilistic inference or more widely within the field of psycholinguistics (Bod, 2009; Jurafsky, 2002). A highly debated and disputed idea within these fields regards the relation between performance and competence. Since the introduction of the Chomskyan dualism between ‘e-language’ and ‘i-language’ (Chomsky, 1965, 1966), it has been debated how these concepts are related - if at all - and whether performance is a valid proxy for an individual’s mental competence to produce language. However, as Leech (1992) points out, these quarrels are often overemphasized, and, although the Chomskyan notion in particular has challenged corpus linguistic studies, there is a consensus in many corpus linguistic research environments that performance and competence are somehow causally related in the sense that performance is a product, though not a 1:1 reflection, of individual competence.

If we turn to Carter’s remaining metagenres, it is clear that it is much more difficult to measure competence within these genres by only looking at textual data. A common feature of these metagenres is that their success criteria are related to aspects that rely on human judgement. A key success criterion for the metagenre *problem-solving* is, for instance, the viability of the suggested solutions, and, similarly, the success criterion for *empirical inquiry* is the validity of results. If competence in such areas is to be measured, one would need scales based on human scoring, such as rubrics. The metagenre *performance* is thus the only genre in which language is an end in itself, and it is therefore much easier to study competence within this area by taking measurements of linguistic features in the text as evidence.

4.2.2 The writing process

Although studies of writing processes are slowly becoming more frequent in writing research, they are still relatively rare. Most of these studies do not rely on textual or linguistic data, but rather on qualitative analyses of alternative data sources such as classroom observations or screen

recordings or on small quantitative analyses of rubric scores or log data. Almond et al. (2012), Leijten et al. (2015), and ten Peze et al. (2021), for instance, examine keystroke log data to study how students use different strategies for revising their texts while writing, and Engblom et al. (2020) use screen recordings from the students' computers to study the types of changes students make to their texts when writing. This shows that it is difficult to study writing processes as they unfold simply by measuring linguistic features in texts; we must instead rely on a larger collection of different data sources.

4.2.3 The student text

It can of course be difficult to distinguish the student text from the other aspects of the model, such as sociocultural framing or the student. The main purpose of traditional corpus linguistic studies, however, has often been to explore recurring linguistic patterns in language use. These studies are conducted to inform linguistic theories (text linguistics, morphology, semantics etc.) rather than pedagogical theories of language learning, and they thus make new connections between language as an abstract system (*langue*) and actual patterns in language use (*parole*) (Biber et al., 1998; Stubbs, 2007). Such purely linguistic studies are rare when studying student texts in educational writing, because the primary endeavor of much educational research is often problem-oriented or aimed at developing educational practice, and linguistic measures are therefore often related, at least indirectly, to phenomena outside the text itself. This means that the student text is often only interesting insofar as it works as a proxy for other more inherently pedagogical phenomena.

An important educational issue related directly to the text itself, however, is that of text quality. A general notion of text quality is difficult to infer directly from computational analyses of texts alone, because we have no parameters for assessing what an appropriate level of syntactic complexity is, for instance. This will inevitably vary from one communicative context to another. One problem is, for instance, that texts can be manipulated and twisted in a way that turn them into meaningless strings of words while still maintaining the same linguistic surface structures. A famous example is the BABEL (Basic Automatic BS Essay Language) generator ¹ developed in 2014, which, based on a limited

¹ The BABEL generator can be found here: <https://babel-generator.herokuapp.com/>

number of keywords, was able to generate gibberish essays that were assigned high scores by a number of machines for automatic essay scoring (Perelman, 2020). Another problem is that text quality in educational contexts is often not derived from functional communicative criteria but rather from metafunctional criteria such as grading or, in Carter's (2007) terms, displaying specific disciplinary kinds of knowing and doing. This means that many measures of text quality rely on holistic scores (e.g. grades or rubric scores) rather than on measures of specific linguistic features. This does not mean, however, that measures of linguistic features are completely separated from a general idea of text quality. Many studies have, for instance, examined which linguistic features predict text quality (see Crossley (2020) for an overview), but as pointed out by, among many others, Beck & Jeffery (2007) and Murphy & Yancey (2007), the features that constitute text quality are relative to genre, task, context and several other variables. Thus, although we can easily calculate which features predict text quality and thus create an aggregate and probabilistic measure of quality, it is much more difficult to calculate text quality of individual texts based on linguistic measures alone.

4.2.4 Instructional framing

As was the case with the writing process, the instructional framing is of course difficult to study directly in student texts without additional data sources. However, it is common in corpus linguistic studies to examine which contextual factors account for variability in student texts, which means that it is possible to examine how a specific instructional design affects linguistic features in student texts. Rouse-Malpat et al. (2019), for instance, studied how two different instructional approaches affected morphosyntactic and lexical features in L2 students' texts, and a meta-analysis by Graham et al. (2012) showed general effects of instruction on different dimensions of writing.

A second research area that relates to instructional framing concerns teacher feedback. Written feedback in the form of either text comments or longer segments of prose is available in digital formats, and, although this practice is still in the very early stages, researchers have been able to create corpora of written teacher feedback. This means that it is possible to study feedback practices by applying tools from natural language processing or other digital tools to study patterns in teachers' feedback practices (see e.g.

Lang, 2018). Another potential application of CL methods within this area is not concerned with written language as such but rather with written records of spoken language, such as classroom dialogue (O’Keeffe et al., 2007). However, at the moment, these studies are very rare.

4.2.5 Sociocultural framing

The final aspect of the model is sociocultural framing, which encompasses both sociocultural (e.g. social background and writing attitude) and linguistic variables (e.g. register, genre, and voice). As to the former, the limits are similar to those previously described with regards to writing process and instructional framing. To study such aspects successfully, we would require more data sources than mere text. With regard to the latter, however, it is different. Large linguistic constructs, i.e. constructs that are shared within a given language community, can of course be studied by means of corpora. Discourse, genre and register, for instance, might manifest themselves differently for each metagenre, but the possibility of studying these constructs is independent of metagenre; in other words, we can study them in all metagenres by only looking at the textual data.

4.3 Implications for writing research

As the above examination shows, the potential of CL methods in writing research is a delicate matter, because it differs from one metagenre to the other. It is a widespread approach to infer from linguistic features to cognitive constructs and to those sociocultural dimensions that are inherently sociolinguistic. However, important dimensions such as writing process and instructional framing are omitted in this process. This clearly has consequences for how to understand the role of CL in writing research.

First of all, the above examination unveils a significant disciplinary imbalance. Those disciplines that make use of the *performance* metagenre are more easily compatible with CL methods than those that make use of, for instance, the *problem solving* or *empirical inquiry* metagenre. By ‘compatible’, I mean that it is easier to measure writing competence in the *performance* metagenre by only taking measurements of linguistic features as evidence. The other metagenres have success criteria that are extralinguistic and thus often rely on some kind of human scoring. The limitations of CL methods in terms of addressing these non-linguistic dimensions thus suggest a need for a multifaceted approach more attuned

to the complexity of educational writing. This means an approach that focuses on a wider range of data types within an overarching educational ecology, an approach that focuses on what Palermo (2017) refers to as *Writing as Analytics*, i.e. writing as socio-cognitive, scripted and transformative processes. Such an approach would also address another significant issue, namely that contemporary digital texts consist not only of linguistic structures but also of a range of other communicative resources such as pictures, layout and colors (Kress, 2010; Kress & van Leeuwen, 1996). Layout, for instance, has proven to be a particularly important area of young children's writing development (Kress, 1994). Linguistic studies must therefore be supplemented with studies of multimodal corpora if we are to gain a better insight into the writing trajectories of school students.

5. Moving the discussion forward

Although increasingly prevalent, the potential of CL methods and tools is still relatively unexplored in educational writing research. As I briefly touched upon in the introduction, the application of CL methods in the humanistic and social sciences raises several important questions. For one thing, it raises the question of how digital tools affect knowledge generated within educational writing research, and, more fundamentally, what it means to study writing on the basis of an integration of humanistic and computational approaches. These are important questions to address, since digital tools are likely to play an increasingly important role in future writing research. It is, however, beyond the limitations of this article to give a detailed account or in-depth discussion of these questions. Instead, I will briefly identify a few theoretical concepts that could provide entry points for further inquiry into these matters.

5.1 Affordances of digital research tools

The first theoretical entry point concerns the role of research instruments. To fully grasp the potential of CL methods and tools, one must take into the account the nature of the research instruments themselves. As pointed out by Baird (2004) in his materialist account of scientific knowledge, scientific instruments are not merely instrumental to the production of scientific knowledge. They are also constitutive. This means that, in different ways, they affect the epistemological underpinnings of different scientific disciplines, because they make certain types of knowledge

available and other types of knowledge unavailable. In parts of the natural sciences this is, for instance, connected to the physical properties of research instruments (e.g. the thermodynamics of mercury in a thermometer). When dealing with digital technologies, however, it is of course insufficient to just take into account the physical properties of the research instruments. Digital technologies also allow for an array of social and communicative actions to be carried out digitally, i.e. by virtue of the digital software of the computer (Berthelsen & Tannert, 2020). This means that, in the case of NLP tools, for instance, there is a digital ‘materiality’ that affects what actions one can and cannot perform by means of the specific tool, which again affects what kind of knowledge is produced.

A way of understanding more thoroughly what this means is to turn to the concept of affordance, which was originally coined by Gibson (1979) in his classical theory of visual perception. Affordances denote possibilities for action (e.g. social, communicative, and aesthetic actions) enabled by the materiality of the physical or virtual environment relative to context and agent; in other words, affordances are not fixed and generic properties of the environment but differ according to who is using them and under which circumstances they are used. The term has been applied to a range of different domains, particularly within the field of technology studies (Hutchby, 2001). In all of these cases, affordance is used to investigate properties in the physical and digital environment of the specific technology that make certain types of action possible. It is therefore possible to also use the concept to refer to the different possibilities for action brought about by digital research tools. The notion of affordance has been sporadically used in research literature to refer to the general idea of ‘potentials’ in research tools. Kyle (2021), for instance, uses the term to investigate the potentials of specific NLP tools for learner corpus research, while Dobson (2019) uses the term in a somewhat wider sense to critically examine possibilities and limitations of computational methods in the humanities and social sciences at large. However, if used in a too general sense an important element of affordances get lost, namely that affordances are not generic properties but are relative to agent and environment. In other words, they are purposefully utilized by an agent with certain dispositions in order to carry out an intended action within a specific context. Thus, affordances can be used as a theoretical basis for examining

the epistemic potentials afforded by different digital tools in relation to very specific scientific disciplines and research questions.

An important aspect of affordances is that they ascribe agency to the individuals utilizing them. This means that it is not sufficient to only focus on the tools as isolated technologies; they must instead be viewed as part of a larger research process involving traditional humanistic approaches. This idea leads me to the second theoretical entry point, one that concerns the role of the researcher in the process of interpreting numerical data.

5.2 Computational hermeneutics and data narration

There is of course no single unified epistemological approach for studying writing. No theoretical perspective covers writing in all of its complexity and different manifestations, and there is no single method (quantitative nor qualitative) or research instrument for adequately describing writing. Consequently, single linguistic measures must be invigorated by being compared and countervailed with other measures or data types before they become part of a broader process of interpretation. The reliance on multiple data sources and interpretational processes has therefore become an important topic in the literature on both writing analytics and digital humanities in general – particularly with a focus on the epistemological relation between computational analysis and hermeneutic interpretation, or, in other words, what has become known as computational hermeneutics.

A useful theoretical contribution in that area is the three types of text reading described by Mohr et al. (2015); thin reading, close reading and thick reading. Thin reading refers to the process of content analysis in which the distribution of key meanings through texts in a corpus is identified and turned into numerical data operable by computers. This process thus groups text in an attempt to find general patterns of manifest meaning without paying attention to subtle semantic differences. This is, however, the case with traditional manual close reading in which the complexity and peculiarities of individual texts are identified and interpreted by human readers, not by computers. With thick reading, on the other hand, the thrust once again shifts towards computational analyses, but this time not in order to reduce complexity but rather to focus on utilizing as many meaningful measures as possible and thereby creating a richer data material that fits one's interpretive intention. It is thus an attempt to bring computational analyses closer to the act of close reading by integrating the

scale of data material in thin reading with the epistemic plurality and textual sensitivity of close reading. This kind of quantitatively based ‘thick description’ does of course not speak for itself but will need to become part of a larger interpretational narrative. Arguing against the idea that data analyses are self-evidentiary, Dourish & Cruz (2018) write: “Data makes sense only to the extent that we have frames for making sense of it, and the difference between a productive data analysis and a random-number generator is a narrative account of the meaningfulness of their outputs.” (p. 8). Narrating data entails structuring and interpreting data within a theoretical frame that supports a more thorough understanding of the data and the analytical outputs. Thus, it is this kind of data-rich and multifaceted approach that would also allow CL studies of writing to merge traditional computational approaches involving abstraction and automation with well-known humanistic approaches involving contextualization and interpretation.

6. Concluding remarks

This article has offered an explorative discussion of the role and potential of CL methods in educational writing research. In one sense, this is a discussion that is particular for writing research, in the sense that it concerns matters such as linguistic representation, writing development and pragmatics. In another sense, however, the discussion of CL and writing research is subsidiary to more general pedagogical concerns about the perpetually scrutinized relation between education and its related scientific disciplines. An immediate concern here is of course whether applications of CL methods in educational writing research will lead to a reduced understanding of writing by ignoring the broader social contexts in which writing practices unfold, and, consequently, whether such a reduced understanding of writing will contribute to an already increasingly reductionist understanding of pedagogical practice and the purposes of education as such (Biesta, 2015; Selwyn, 2015). What we have learned already from introducing fields such as learning analytics into educational research is their potential to cause a great divide between data science and other areas of educational research, such as the philosophical or anthropological areas. This divide stems - at least to some extent - from the uncritical promise of prosperity that sometimes comes with data science, such as promising quick-fixes to long-lasting educational problems. It is

perhaps more fruitful to engage in specific discussions on what data can and cannot say in relation to very specific research questions. This also applies to the discussions on CL. Educational writing is not a uniform practice. It relates to very different disciplinary situations and contains different communicative criteria, and the discussions that we ought to have on the potentials of CL for studying writing should pay more attention to this heterogeneity.

In this article, I have therefore attempted to highlight the need for an approach to writing research that accommodates critiques of reductionism and technocentrism by bridging the gap between technology-centered and human-centered approaches for studying writing. It is of course nothing new to claim that data analysis and interpretation go hand in hand, but this perspective is often lacking in many discussions on the potential of CL and data science at large, particularly in discussions on policymaking (Berthelsen & Tannert, 2019). This means that too much emphasis is put on the data itself without paying sufficient attention to how this data can be meaningfully interpreted and made sense of within an educational framework, which by nature is normative and contested. Such aspects are, however, vital to consider further if we are to successfully integrate CL methods in educational writing research.

Notes

ⁱ K12 is an American collective term for all the educational stages from kindergarten to the 12th grade.

ⁱⁱ A text act is Togeby's (2010) term for a series of related sentences (a text) that constitute one coherent act, rather than a series of independent speech acts.

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Morten Tannert
Scandinavian Studies in Language, 12(1), 2021 (1-29)

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