Speech as a writing tool:

An exploratory study of speech-to-text technology in lower secondary education

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Summary

Speech-to-text (STT) technology enables pupils to write using their voices and is considered a viable alternative to handwriting and typing for those with writing difficulties because it reduces the constraints of transcription (Arcon et al., 2017). Research indicates that students with learning difficulties can produce higher-quality compositions when dictating texts to a scribe compared with writing by hand or typing (De La Paz & Graham, 1997; Gillespie & Graham, 2014). Similar outcomes have been observed among children without learning difficulties (Hayes & Berninger, 2009). Given the sensitive emotional development and attitudes of pupils in lower secondary school, the social implications of using STT technology among this age group are an important consideration with respect to creating inclusive classroom environments. Inclusive education has been described as a response to increasing diversity guided by the aim of empowering all learners, celebrating differences in dignified ways and not leaving anyone out (Barton, 1997). Schools are now in a position where they must decide whether this technology should be accepted as an assistive tool available only to a certain group of students, as a tool for all learners or not used at all. To address these issues, the present project explores how teachers and school leaders at a Norwegian lower secondary school introduced STT technology as an option for all students during writing activities.

The aim of this project is to explore the potential of STT as a writing tool for lower secondary education pupils with writing difficulties. The project comprises three studies. Study 1 is a scoping review of empirical research on the use of STT among secondary pupils with learning difficulties published from January 2000 to April 2022. Study 2 explores teachers' perspectives of STT as an inclusive approach in secondary education through focus group interviews. Study 3 explores the use of STT as a writing modality through analyses of screen recordings and interviews with pupils with low writing achievement. The results of Study 1 indicate that very little research has been conducted on the use of such technology for adolescents with learning difficulties at the secondary education level. The review identified eight peer-reviewed studies and five publications of grey literature. Areas of interest include five topics: writing-related skills, text assessment, writing processes, accuracy of the technology and participants' experiences. The findings further indicate that writing performance among pupils with learning difficulties is improved when using STT and that parents, teachers and pupils report positive experiences with using the technology. The results from Study 2 regarding teachers' experiences of STT as an inclusive approach reveal that the implementation of STT technology challenges different aspects of inclusion. Furthermore, teachers primarily considered STT an assistive

technology that is useful for pupils with writing difficulties. Yet, they also reported that the technology offers opportunities for all pupils to participate in collaborative writing tasks, discuss norms for formal and informal languages and produce first drafts without having to worry about spelling. In addition, whilst STT provides academic opportunities for most learners, it is also described as a disruptive and embarrassing element in a whole-class environment. Finally, the results from Study 3 reveal that pupils with low writing achievement could not rely on STT to be 100% accurate and to provide correct orthography and syntax in Norwegian. Such findings suggest that technological issues must be addressed and that sufficient practice is necessary before STT can be implemented as a truly beneficial tool for adolescents with low writing achievement within the context of Norwegian secondary education.

List of Articles:

Article 1:

Matre, M. E., & Cameron, D. L. (2022). A scoping review on the use of speech-to-text technology for adolescents with learning difficulties in secondary education. *Disability and Rehabilitation: Assistive Technology*, 1–14. https://doi.org/10.1080/17483107.2022.2149865

Article 2:

Matre, M. E. (2022). Speech-to-Text Technology as an Inclusive Approach: Lower Secondary Teachers' Experiences. *Nordisk tidsskrift for pedagogikk og kritikk*, *8*. https://doi.org/10.23865/ntpk.v8.3436

Article 3:

Matre, M. E. (In press). An Exploratory Study on the use of Speech-to-Text Technology as a Writing Modality for Pupils With low Writing Achievement in Norwegian Lower Secondary Education. *Nordic Journal of Literacy Research*.

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1 Introduction

A number of writing technologies have been discovered and developed since the earliest forms of writing first appeared almost 5500 years ago in Mesopotamia (Matthews & Richardson, 2018). In the last century, pupils have been taught to write with ink, pen, pencil, typewriters, and computers. Writing by speech is considered the most recent technology despite the invention of the phonograph—the forerunner of speech technology—by Thomas Edison in as early as 1877 (Millard, 2005). Indeed, the development of functional writing tools takes time, and even though technology is available, it does not necessarily mean that it is feasible in an educational context.

Speech-to-text technology (hereafter referred to as 'STT') converts spoken language into digital text and is also referred to as '(digital) dictation', 'speech recognition' or 'speech technology'. Yet 'speech technology' is a broader term that may also refer to other speech-based technologies, such as voice commands and text-to-speech (TTS). STT is the only speech technology explored in this thesis. Automatic speech recognition is one of the oldest applications of artificial intelligence (Yu & Deng, 2016). It employs learning algorithms that improve the accuracy and quality of the technology over time. Given that only licenced software, such as Dragon Speak (Nuance®), has been previously available, STT has been considered to be an expensive alternative to typing and handwriting and primarily for pupils with a documented need for writing assistance. At present, STT is integrated into most computer and tablet software and therefore openly available to teachers and pupils in Norwegian lower secondary education.

STT has also been studied in educational settings for several decades. Early studies by Olson and Wise (1992), Raskind and Higgins (1995) and Elkind et al. (1996) have shown that both effect and exploratory studies have been conducted on the use of STT at the primary and secondary education levels. These studies present speech technology as a form of assistive technology (AT), a kind of technology for pupils with disabilities. However, as this proved to be expensive software, students had to present documented special needs to be allowed to use speech technology in the classroom. Today, recent technological advances have made speech technology available on most devices without additional expenses; thus, STT can now be considered a writing tool that is available to most students who have access to a computer or tablet. However, how students interpret the relevance of speech technology may be an influential factor in their adoption of this technology. If an approach, tool or methodology is defined as a special aid, students may be reluctant to use it. Polgar (2011) argues that AT is not neutral, and the meaning that technology holds for the user is a key determinant of whether a device will be used or abandoned. Thus, whilst STT could be considered a tool to achieve a desired

writing activity, it may also be perceived as a visible sign of a disability, thus reinforcing the social stigma associated with the disability.

Little research exists on the use of STT in secondary education or on the effects of introducing this technology to adolescent learners with or without writing difficulties (MacArthur, 2009; Perelmutter et al., 2017). Still, different forms of AT, such as STT, are widely recommended in the individual education plans (IEPs) of students with special educational needs (Edyburn, 2004; Peterson-Karlan et al., 2008) and are often recommended in policy documents and teaching materials (Cochrane & Key, 2020; Watkins, 2014). Previous research on STT in educational contexts predominantly represents English language users, both in studies comparing its potential for pupils with and without learning difficulties (Higgins & Raskind, 2000; MacArthur & Cavalier, 2004; Quinlan, 2004) and for pupils learning English as a second language (Arcon et al., 2017; Shadiev et al., 2017).

Studies on the use of STT in primary and secondary education in the United States generally indicate its positive effects on text length and quality; however, these findings are often inconclusive (Higgins & Raskind, 2000; Quinlan, 2004). For example, a study of high school pupils writing by hand, dictating to a scribe and dictating to a computer showed that the pupils produced higher text quality when dictating to a scribe. Indeed, both forms of dictation led to higher text quality compared with handwriting (MacArthur & Cavalier, 2004). Quinlan (2004) compared a group of fluent (n=20) and less fluent writers (n=21) composing narratives with STT and by hand and found that the latter produced significantly longer narratives with fewer errors when writing with STT; however, STT did not improve text quality. Moreover, for the fluent writers, there was no significant difference in text length or accuracy between the two writing conditions. In a study of 45 5th grade Canadian pupils, Haug and Klein (2018) examined the use of STT as a writing strategy by randomly assigning pupils to compose by hand (n=22) or STT (n=23). Similar to Quinlan (2004), Haug and Klein (2018) found no difference in text quality between the two conditions. The differences in the results presented in previous STT research may be explained by variations in how the technology was introduced or the amount of practice provided to participants. For example, the pupils in Quinlan's (2004) study took part in a 6-hour writing class and learnt to use STT, whilst the participants in Higgins and Raskind's (2000) study practised using STT for 50 minutes per week for 16 weeks.

Thus far, no scientific study has been published on the use of STT in Norwegian lower secondary education (Matre & Cameron, 2022). As STT technology is already available to most Norwegian pupils, and studies (MacArthur & Cavalier, 2004; Quinlan, 2004) have shown that it may be a feasible writing approach for pupils with writing difficulties, the aim of the present thesis is to

explore the potential of STT as a writing tool for pupils with writing difficulties at the lower secondary education level.

1.1 Background

1.1.1 Writing

According to the Merriam-Webster dictionary (n.d.), *writing* is defined as the act or practice of literary or musical composition. The scope of this thesis is writing as text composition in an educational context. In the literature, writing has been investigated from several theoretical perspectives, including cognitive processes underlying text production (Hayes, 2012; Hayes & Berninger, 2014), the coordination of writing processes (Olive, 2014) and text analyses using a variety of measures, such as discourse (Saarinen, 2008), semantics (Roberts, 2020) or syntax (Sadiah & Royani, 2019). 'Literacy' was originally considered a central concept in the present thesis. However, the scope is narrowed down to writing and the aspects of text composition that may be explored, given that it is a broad term that may include reading, writing, speaking and listening (Jacobs, 2014), as well as social and cultural practices (Bazerman, 2016; Street, 2009) or an episteme rather than a skill or a competence (Brockmeier & Olson, 2009). The data for the thesis were mainly collected through interviews with teachers and pupils, as well as video analyses of text composition. Thus, the three main aspects of writing explored in this thesis are the pupils' social and academic experiences of producing text with STT; composition elements such as transcription accuracy, fluency and revision processes; and teacher's experiences of introducing STT as an inclusive approach.

1.1.2 Writing Difficulties

Several terms can be used to describe pupils who struggle with writing. Some pupils have been diagnosed with a learning disability, whilst others may not have been diagnosed but still struggle with writing tasks. The terminologies that were selected to describe the samples evolved with the project to adhere to the specific frameworks of the studies. In Article 1, I chose to use the term *pupils with learning difficulties,* whilst in Article 2, I used *pupils with reading and writing difficulties.* The aim was to use terminology that could include struggling writers with and without diagnosed disabilities, thus facilitating subsequent analyses of the different aspects of inclusion. In Article 3, a third term was introduced, *pupils with low writing achievement,* as this was the selection criteria for the sample in the study. 'Low-', 'medium'- and 'high' writing achievements are phrases typically used in the Norwegian Curriculum and on national tests to refer to the different levels of mastery. Currently, there is no national test measuring writing achievements in Norwegian lower secondary education; only a national test of reading proficiency. Given that reading and writing skills are correlated (Fitzgerald & Shanahan, 2000),

the national test for reading was used to identify pupils who are likely to have low writing achievement. On the national tests for reading, pupils can achieve scores at five different levels. Levels 1 and 2 are described as low levels of achievement. Pupils who performed at Levels 1 and 2 on the national tests for reading were considered to have low writing achievement and were therefore invited to take part in Study 3. The term *pupils with writing difficulties* was used as it is a more established concept in international writing research and gives a more accurate description of the participants in this study compared with *pupils with special educational needs* or *pupils with writing or learning disabilities*.

1.1.3 The Norwegian Writing Curriculum

The Norwegian Curriculum describes different levels of attainment that pupils should reach in each subject. Attainment targets define what they should master after completing years 2, 4, 7 and 10 of the primary stages, as well as years 11, 12 and 13 of the upper secondary stages (The Norwegian Directorate for Education and Training, 2019a). Several attainment targets are related to the skill of writing. In the new Curriculum, gradually implemented in Norwegian schools since August 1, 2020, the modalities of writing described are handwriting and writing on a keyboard. Moving from the attainment targets by the end of year 2 to the end of year 7, students are supposed to develop skills, including being able to write texts by hand and on a keyboard and being able to write texts with *functional handwriting* and write *fluently* using a keyboard (The Norwegian Directorate for Education and Training, 2019b). Other modalities of text production, such as STT technology, are not described in the attainment targets. However, the framework of core skills states that students should be able to choose relevant writing strategies as a basis for writing.

Alongside reading, numeracy, digital and oral skills, writing is one of the five foundational skills described in the Norwegian core curriculum for primary and secondary education and training. This framework of five basic skills has been implemented since 2012 and is a supplement to the attainment targets described in the Curriculum. In the subject Norwegian, 'writing' is defined in the curriculum as the

> (…) ability to express oneself in a wide range of fictional and factual genres. This means developing personal written forms of expression and mastering writing strategies, spelling and text composition. Writing is also a way of developing and structuring thoughts and a method for learning. The Norwegian subject has [a] special responsibility for developing written skills. The development of writing skills in Norwegian ranges from learning basic writing to planning, formulating and editing texts in various genres and

adapted to the purpose, medium and receiver. (The Norwegian Directorate for
Education and Training, 2019a, pp. 4–5).

In the current Norwegian educational reform, specifically the Curriculum for
Knowledge Promotion in Primary and Secondary Education and Training
(Norwegian Ministry of Education and Research, 2006), all subject-specific
curricula describe how the five basic skills contribute to the development of pupils'
competences and qualifications and how they are integrated into each subject. Thus,
when students are expected to be able to choose relevant writing strategies, this can
be considered both a learning strategy and a core skill. Compared with reading,
where students, according to attainment targets by the end of year 10 shall reflect
upon and describe their reading strategies, there are no explicit requirements in the
Curriculum for the subject Norwegian (Language Arts) to reflect upon different
strategies of writing.

1.1.4 Writing and Technology in Education

According to Myhill et al. (2022), the repertoire of writing activities has, in recent
decades, expanded exponentially and brought about a democratisation of writing and
publishing. With digital technologies, new approaches have emerged, such as e-
mailing, texting, chatting, blogging or tweeting (Myhill et al., 2022). However, in
the educational context, teachers and school leaders must make well-informed
decisions on how and to what degree digital technologies may or may not be
introduced and used during writing activities. In a review on the use of technology
and writing activities in education between 2002 and 2017, Williams and Beam
(2019) found that teachers' beliefs about technology influence their willingness to
use information and communication technologies (ICTs) to mediate writing
instruction and writing-related activities. Furthermore, the authors identified two
primary assumptions that prevented teachers from implementing digital technology
during writing activities: (1) teachers worried that word processors could place
greater cognitive demands on students compared to using paper and pen, and (2)
students' development in spelling could be hindered if they were allowed to use the
spellcheck feature. Furthermore, researchers have raised critical questions regarding
the use of technology in education. For instance, Blikstad-Balas et al. (2020) label
current educational practices a digital experiment and argue that even though digital
technologies surround us in everyday life, they should not automatically play such a
prominent role in education.

     Within the context of special education, academic discussions regarding
writing and technology have traditionally revolved around certain topics, such as
rights, disabilities, possibilities and barriers (Edyburn et al., 2005; MacArthur,
2009). In contrast to more general debates on the educational benefits and

constraints of using digital technologies, special education researchers have, to a larger degree, taken for granted that some learners require digital technologies to take part in education and develop relevant skills and proficiencies. This is illustrated by a quote from Mary Pat Radabaugh, Director of the IBM National Support Center for Persons with Disabilities:

> For most people, technology makes things easier. For people with disabilities, however, technology makes things possible. In some cases, especially in the workplace, technology becomes the great equalizer and provides the person with a disability a level playing field on which to compete. (McMahon & Walker, 2019, p. 77)

McMahon and Walker (2019) acknowledge that there is a limited and, at times, non-existent evidence supporting the implementation of different digital technologies in special education. Still, they argue that educators must use their best judgement and make decisions based on the premise of the least dangerous assumption. This premise was presented by Donnellan (1984), who stated that 'in the absence of conclusive data, educational decisions ought to be based on assumptions which, if incorrect, will have the least dangerous effect on the likelihood that students will be able to function independently as adults' (McMahon & Walker, 2019, p. 78). Therefore, the assumption in special education is that to create inclusive and accessible learning environments, pupils must be provided digital technologies, even though there has been limited research supporting this decision.

Writing is essential in education. Pupils write to learn, to communicate and to organise and share their knowledge. Yet, becoming a proficient writer is not an easy task (Graham, 2019). Pupils with writing difficulties are at a disadvantage during academic and social writing activities if they are not provided with alternative approaches or instructions that can help increase their capabilities. In this regard, STT has been presented as a suitable alternative to handwriting and typing, as it reduces the constraints of transcription (Arcon et al., 2017). Given that STT technology is recommended in IEPs and very little research on its use in lower secondary education has been conducted, there is a great need to explore STT technology as a potential writing tool for pupils with writing difficulties.

1.2 Research Question and Thesis Outline

Table 1. Overview of the Research Aims, Methods, Sample and Articles

Main research question: What potential lies in speech-to-text technology as a writing tool for pupils with writing difficulties?			
	Article 1	Article 2	Article 3
Explores the potential of STT	…in previous research on secondary pupils with learning difficulties	…as an inclusive approach described by teachers in lower secondary education	..as an approach to writing for pupils in lower secondary education with writing difficulties
Aim	To identify and describe the aims, approaches and findings of studies on the use of STT among secondary pupils with learning difficulties published from January 2000 to April 2022	To explore the benefits and challenges inherent to STT as an inclusive approach for the teaching of writing in Norwegian lower secondary education	To explore the benefits and constraints of using STT for pupils with low writing achievement in Norwegian lower secondary education
Methodological approach	Scoping review	Focus group interviews and observations	Stimulated recall and analysis of screen recordings

This study posts the overarching research question, *'What potential lies in STT as a writing tool for pupils with writing difficulties?'* Even though STT was introduced to all pupils during this study, the main emphasis was on exploring its potential for pupils with writing difficulties. This problem is explored from different angles in the three articles. Article 1 explores the potential of STT through empirical research on the use of STT in lower secondary education. Article 2 examines teachers' experiences of STT as an inclusive approach. Article 3 investigates the writing

strategies and experiences of pupils with writing difficulties regarding their use of STT when producing a reflective text. An overview of how the three articles relate to the overarching research question is illustrated in Figure 1.

Figure 1. Overview of the Research Project
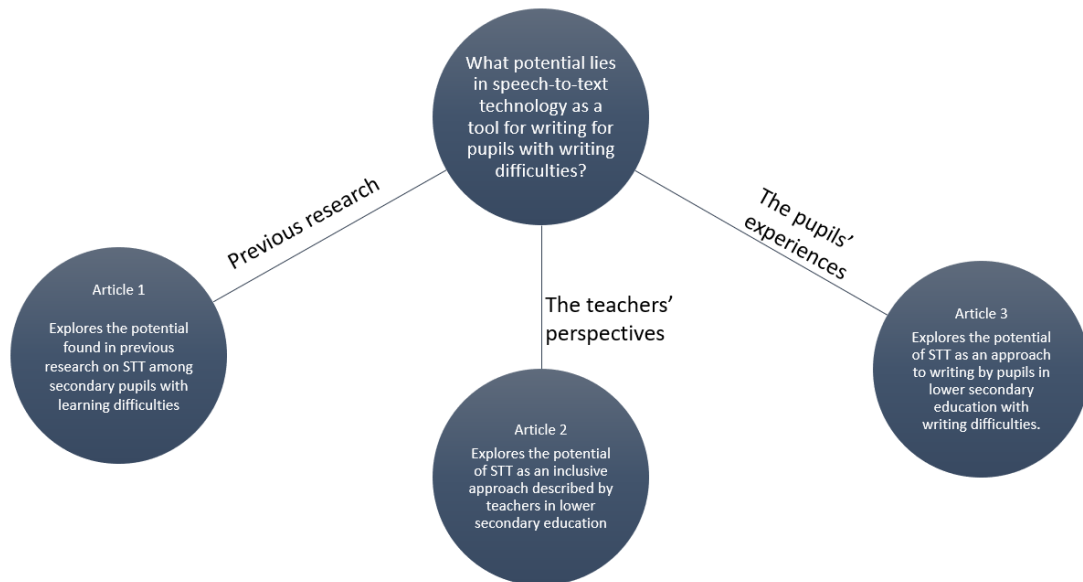
2 Theoretical Frameworks

2.1 Writer(s)-Within-Community Model

Writing within educational contexts concerns learning to write, writing to learn and developing sufficient strategies, such as conveying content knowledge, reflecting and expressing opinions in text, formulating sound arguments and acquiring a variety of genres. Research on how pupils learn to write and develop as writers has been conducted from different theoretical perspectives. For example, cognitive research focuses on the writing process of the individual writer, sociocultural theories investigate writing as a social practice and linguistic studies explore grammatical structures and other aspects of a produced text (Chen et al., 2020). This interdisciplinary project considers linguistic elements in pupils' texts, the individual writers' experiences of producing text with STT (Article 3) and teachers' experiences of introducing STT in the sociocultural environment of lower secondary education (Article 2). Therefore, I have chosen to employ Graham's (2018) revised writer(s)-within-community (WWC) model, which is a theoretical model that includes sociocultural, linguistic and cognitive perspectives on writing. The WWC model builds on previous sociocultural (Bazerman 1994; Lave & Wenger, 1991) and cognitive models (Hayes 1996; Kellogg 1996) and aims to expand on these theories to show that writing is shaped and constrained, not only by the writer or the context, but also by the capabilities and perceptions of writers and collaborators as well as the interactions between them (Graham, 2018, p. 258). The model presents two components: (1) the basic components of a writing community and (2) the cognitive mechanisms involved in writing.

The component describing the cognitive mechanisms involved in writing is similar to a developmental model of writing featured in *The Simple View of Writing* (Berninger & Amtmann, 2003), which describes writing as an interaction between three cognitive processes of transcription, self-regulation and text generation, all of which are governed by working memory. These components are also present in the descriptions of cognitive mechanisms involved in writing in the WWC model; however, in this case, the individual writer is set in a context involving other individuals, including readers, collaborators, teachers, mentors or peers. For example, when describing how long-term memory resources are involved in writing, the WWC model not only describes the resources of the individual writer but also includes the knowledge and beliefs of the people who will be reading, assessing or providing feedback on the text (i.e. the writing community).

At the centre of the community component of the WWC model (Graham, 2018) are tools, written products, actions and goals. Thus, the role of the writing tool (e.g. STT) is integrated into the model, and it closely relates to actions, goals and written products. Furthermore, the model shows that the kind of writing tool used

both influences and is influenced not only by the writer, but also the collaborators; the physical and social environment; the writing community's collective history, purposes and members; and prevailing historical, political, institutional, cultural and social forces. Therefore, employing this model as a theoretical framework to analyse the potential of STT in a Norwegian lower secondary school context can shed light on the complex relationship between the writing community and the cognitive mechanisms involved in writing when using this specific writing tool. The WWC model provides an overarching framework for analysing the use of STT for writing activities in a lower secondary context. This is because it draws the lines between the historical context of writing with STT (as discussed in the scoping review in Article 1) as well as the institutional and political context of STT as an inclusive approach in lower secondary education (Article 2). The model also describes the components that influence how adolescents with low writing achievement use STT in a Norwegian lower secondary education context (Article 3).

Writing difficulties are mentioned in the WWC model. However, the disability or deficit aspect is not emphasised in this model (Graham, 2018) in contrast to diagnostic manuals, such as The Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association [APA], 2022) or the International Classification of Diseases (ICD-11; World Health Organization [WHO], 2019a), which are used by medical and educational professionals to identify writing disorders. According to the DSM-5, a specific learning disorder is a kind of neurodevelopmental disorder that impedes an individual's ability to learn or use specific academic skills, such as reading, writing or arithmetic (APA, 2013). In addition, the WHO's most recent classification in the ICD-11 introduces subcategories of writing disorders, such as dyslexia and developmental learning disorders with impairment in written expression (WHO, 2019a).

Both dyslexia and developmental learning disorders are defined based on deficits in cognitive abilities. For example, Snowling et al. (2019) define 'dyslexia' as a neurodevelopmental disorder that causes difficulty in learning to decode and spell, which is typically associated with phonological deficits. 'Developmental learning disorder with impairment in written expression' is defined as 'significant and persistent difficulties in learning academic skills related to writing, such as spelling accuracy, grammar and punctuation accuracy, and organisation and coherence of ideas in writing' (WHO, 2019b). Rather than focusing on individual inherent disabilities and disorders, Graham (2018) describes the essential components of writing as goals, tools, products and actions, along with social, cultural and other structures in the writing community and individual capabilities. One of the aims of the present thesis is to explore the potential of STT for pupils with writing difficulties in the context of inclusive education rather than to compare its potential for pupils with different writing disorders. Thus, the WWC model is a

suitable framework because it provides the opportunity to explore social, academic and institutional factors that may influence teachers and adolescent writers when STT is introduced in the lower secondary education context.

2.2 The Capabilities Approach

The notion of *capability* is central to Graham's (2018) WWC model because some of the tenets describe community or individual capabilities as central elements in writing development. In this regard, a capabilities perspective on education builds on economist Amartya Sen's (1992) *Capabilities Approach,* which was further developed by the philosopher Marta Nussbaum (2000; 2009; 2011). The capabilities approach was first proposed as a reaction to a narrow utilitarian perspective, wherein the development of specific skills required for economic productivity can be considered a principal driver of education (Cockerill, 2014). Central to the capabilities approach is the notion of *equality*, which is described as a person's opportunity to achieve valuable functionings and freedom to promote objectives one has reasons to value (Sen, 1992, p. xi). According to Nussbaum (2009, p. 331), laws that secure equality and entitlements are especially important for people with disabilities because they may not experience equal access to education without costly and considerable changes in the existing methods of instruction.

Lim (2020, p. 573) ties the capabilities approach to inclusive education and states that '[t]he focus of the capabilities approach is on what people are able to be or able to do within a given environment to achieve their well-being.' Similar to Graham's (2018) descriptions of the influential writing community in the WWC model, Lim (2020) posits that the social, political and cultural contexts influence what a person is able to achieve. These ideas further connect to the WHO's (2011, p. 5) classification of functioning, disability and health as an interaction between personal factors, environmental factors and activities. Thus, a political, social and cultural environment that supports alternative approaches to writing, such as STT, may increase pupils' capabilities and simultaneously reduce excluding barriers during writing activities. In the current thesis, capabilities are explored as an alternative educational perspective on writing, which emphasises the agency of the child (Sen, 1992; Terzi, 2014) and what they can do with the writing modalities available to them rather than their skills or deficits.

The medical model presents disabilities as individual deficits or medical phenomena that result in limited functioning or learning difficulties in educational contexts, whereas the social model defines disabilities as the relationship between people with impairments and a disabling society (Anastasiou & Kauffman, 2013; Haegele & Hodge, 2016). Different perspectives on disabilities have influenced the terminologies used to describe learning difficulties. For example, from a medical perspective, pupils are referred to as pupils *with* learning difficulties, whereas from a

social perspective, they are referred to as pupils *experiencing* difficulties. According to Terzi (2005), the capability approach to education moves beyond the dilemma of disabilities as either medical attributes or social constructs. Describing disabilities as inherently relational, the capability approach is less concerned with whether a disability is biologically or socially caused and instead emphasises the environment and alternative functionings. 'Functionings' are described as 'the beings and doings that individuals have reason to value. Walking, reading, being well nourished, being educated, having self-respect or acting in one's political capacity' (Terzi, 2005, p. 449), whereas 'capabilities' are described as the opportunity and freedom people have to achieve such valuable functionings.

In relating writing and STT to capabilities, learners who are provided with alternative writing approaches tend to develop increased capabilities. This is because they may experience more freedom to achieve valuable written functionings, especially if they experience barriers when typing or writing by hand. When or whether writing barriers (e.g. difficulties in learning to decode and spell) are reduced or removed is not the focus of the capabilities approach. Rather, it implies that STT, if introduced as part of the curriculum, may provide more equal opportunities for all pupils in future writing activities. Although not directly referencing STT, Terzi points out that the capability approach suggests:

> [A]n important focus on the demands of equality, as well as quality of educational provision as perhaps more fundamental than questions on the specific location of education, which have long dominated the debate. Simultaneously, it places the well-being and the agency of all children, and children with disability and difficulties in particular, at the centre of the educational process. These dimensions entail reconsidering schooling systems not only in terms of policy, but also of curricular elements and teaching and learning strategies. (Terzi, 2014, p. 480)

Providing alternative approaches to writing, such as STT, is an example of a learning strategy that may increase equality among adolescent pupils and strengthen the capabilities of those with writing difficulties.

2.3 Assistive Technology Frameworks

Different terminologies have been used to describe how technology mediates writing in education. Terms such as 'educational technology', 'instructional technology' or 'writing technology' are used in mainstream education (Little et al., 2018; Strobl et al., 2019), whereas 'assistive technology' is often used in the field of special education (Edyburn, 2006; Peterson-Karlan et al., 2008). AT is defined as the

[D]evelopment and application of organised knowledge, skills, procedures, and policies relevant to the provision, use and assessment of assistive products. An assistive product is any product (including devices, equipment, instruments, and software), either specially designed and produced or generally available, whose primary purpose is to maintain or improve an individual's functioning and independence and thereby promote their well-being. (Khasnabis et al., 2015, p. 2229)

AT can be introduced to support pupils with highly diverse needs, such as those with intellectual, physical, neurological or sensory disabilities (Chambers, 2020). Chambers (2020) further presented AT on a continuum from low-tech to high-tech devices and tools, arguing that it is often less expensive and easier for educators to introduce low-tech rather than high-tech AT. Examples of low-tech devices are pencil grips, adaptive tablet holders and graphic organisers. These are followed by mid-tech AT, which are reasonably priced devices that require less training compared with high-tech AT. Examples include audiobooks, specialised calculators and reading pens. Finally, high-tech devices such as eye-gaze systems, TTS software and word prediction are considered best suited for pupils with significant disabilities or those with extensive functional needs (Chambers, 2020). In this continuum from low to high-tech, STT is considered a high-tech AT.

Peterson-Karlan et al. (2008) define 'assistive writing technology' as a compensatory tool that aims to support pupils who struggle to write and provide scaffolding for basic writing skills. Such technology, however, is not intended to replace other writing approaches but to support pupils in some areas of the writing process, such as during drafting and revision. Edyburn (2006) suggests that special education teachers should consider the remediation versus compensation question as part of the AT consideration process and that they must decide individually as to what degree of time and effort should be devoted to writing remediation and compensation. Similarly, in a systematic review of AT interventions for adolescents and adults with learning disabilities (LD), Perelmutter and colleagues (2017) concluded that AT interventions can be helpful for people with LDs, although it is also important to adapt and customise the intervention. According to US federal legislations, such as the Individuals with Disabilities Act (IDEA, 2004), general educators, special education teachers, parents and other caregivers are required to consider AT services when making IEPs for pupils with special educational needs (Park et al., 2022). The Norwegian Education Act (1998) states that 'pupils who either do not or are unable to benefit satisfactorily from ordinary teaching have the right to special education' (§5.1) and that an expert assessment of the pupil's needs is required (§5-3). Thus, Norwegian legislation regarding special education does not

explicitly mention the use of AT in IEPs. However, the guidelines from the Norwegian Directorate for Education and Training (2021) state that pupils may use AT, such as STT, regardless of special educational needs, especially when this is a prerequisite for demonstrating subject knowledge on a test or exam.

Edyburn (2006) refers to an implicit decision between compensation versus remediation, suggesting that teaching professionals should also consider the aim and purpose of introducing AT, such as STT. In other words, educators must decide whether STT should be used to compensate for low writing achievement or to remediate writing deficiencies. Furthermore, this decision should not be a dichotomy of either remediation or compensation but an ongoing evaluation of the percentage of, for example, the time or effort devoted to writing instruction (remediation) and text composition (compensation) for each pupil (Edyburn, 2006).

2.4 Inclusive Education

Inclusion is connected to the right to education for all, as affirmed in the Declaration of Human Rights (United Nations, 1949), the Salamanca Statement (UNESCO, 1994) and the Convention on the Rights of Persons with Disabilities (United Nations, 2006). However, the notion of inclusion was introduced to secure equal access to quality education for pupils with special educational needs and disabilities (SEND). Extensive conceptual and empirical research has been conducted on inclusion, yet there are still several interpretations of the concept and little agreement as to how it should be carried out and defined in an educational context (Artiles et al., 2006; Göransson & Nilholm, 2014; Keles et al., 2022).

In a critical study of research on inclusive education, Göransson and Nilholm (2014) identified four different understandings of inclusion categorised from A to D and related hierarchically to one another. Therefore, 'the four definitions can be seen as employing stricter criteria concerning what counts as inclusive education as one goes from definition A to D' (Göransson & Nilholm, 2014, p. 268). Studies in Category A used the term 'inclusion' to refer to the placement of pupils with SEND in general education classrooms. Category B articles regarded inclusion as meeting the social and academic needs of pupils with SEND, whereas studies in Category C defined 'inclusion' as meeting the social and academic needs of all pupils. Category D studies also considered inclusion to be a creation of communities that acknowledge specific values, such as equity, care, justice and diversity.

Haug (2017) introduces opposing definitions of inclusion and labels them the 'narrow' and 'broad' interpretations. According to a narrow interpretation of inclusion, which is similar to Categories A and B in Göransson and Nilholm's categorisation, the concept mainly regards pupils with SEND and how to bring about pedagogical changes to meet the needs of such pupils in general education classrooms. A broad interpretation, similar to Göransson and Nilholm's C and D

categories, considers inclusion as something that concerns all pupils, not just those with SEND. Thus, perspectives on inclusion either emphasise adaptations made for individuals with SEND according to a narrow interpretation or adaptations made to the entire learning community, according to a broad interpretation. This distinction is in contrast to the WWC model, which does not emphasise a dichotomy between individual writers and the writing community but rather highlights how writing is 'simultaneously shaped by the community in which it takes place and the cognitive capabilities and resources of community members who create it' (Graham, 2018, p. 271).

3 Methods

3.1 The STIL Project

This PhD project was part of a larger project funded by the Norwegian Research Council named Speech Technology for Improved Literacy (STIL). The STIL project was a collaboration between the Norwegian National Service for Special Needs Education (Statped), two secondary schools and three research institutions (the University of Agder (UiA), Østfold University College and the Norwegian University of Science and Technology). The project was conducted from 2019–2021 and aimed to develop and evaluate an intervention based on STT technology to improve writing skills among Norwegian 8th-, 9th- and 10th-grade students. The research group planned a quasi-experimental study with an intervention school (52 pupils) and a comparison school (131 pupils) to examine changes in writing performance as a result of the STT intervention.

The intervention was planned for 12 weeks from the end of January until the middle of April 2020. However, the quasi-experiment became impossible to conduct because the COVID-19 pandemic forced all Norwegian schools to close from March 12, 2020. The pandemic and the social distancing measures that followed, due to the attempt to prevent the spread of the virus, affected the methodological decisions made for the second and third articles in this thesis. In particular, the research group had limited access to teachers and pupils at both schools and was not able to collect post-test data immediately after the intervention. As it was impossible to complete the quasi-experiment, alternative research designs and other methodological approaches for data collection and analysis were considered for this thesis, particularly explorative research design and in-depth data collection approaches, such as video analysis, observations and different interview techniques (e.g. individual, focus groups and stimulated recall).

3.2 Research Design

The choice to move to an exploratory research design was bolstered by findings from Article 1, which showed that very little previous research had been conducted on the use of STT in the lower secondary education context. In addition, some of the materials already collected for the quasi-experiment, such as lesson plans and transcripts from pre-intervention interviews with teachers, were also applicable for an exploratory study. Therefore, I decided to approach the intervention school and ask permission to conduct follow-up interviews with a group of teachers (for Article 2) and stimulated recall interviews with a group of pupils with writing difficulties (for Article 3). Swedberg (2020) defines exploratory research in the social sciences as an attempt to discover something new and interesting. The two most common forms of exploratory research are characterised by either being on a topic that has

not been previously researched or a topic that has been somewhat explored with the aim of producing new ideas and hypotheses but was left unverified (Swedberg, 2020, p. 18). Thus, an exploratory design has a different aim than an experimental design, in which the purpose is to confirm or reject a hypothesis by collecting data from large samples and generalising findings to the population. Whilst quasi-experimental studies aim for representative samples, the aim of an exploratory sample is to generate insights and information. Exploratory studies are often small-scale studies that usually employ qualitative research methods (Denscombe, 2017). Thus, I chose an exploratory research design because I was able to conduct a small-scale study at the intervention school and gather insights into this relatively unexplored area of research on the experiences of Norwegian lower secondary pupils and teachers who used STT.

3.3 Research Paradigms

I positioned my project as overlapping a post-positivist and constructivist research paradigm as I have used methodological approaches that build on these ontological and epistemological ideas and research traditions (Guba & Lincoln, 2005). For example, I considered some areas of writing possible to discover with the use of test instruments that measured constructs, such as writing difficulties, spelling proficiency or semantic knowledge, in line with a post-positivist research paradigm. At the same time, I considered these elements and other aspects of writing, such as writing capabilities and inclusion, as alterable and context-dependent social constructs. The ontology of post-positivism has been referred to as 'critical realism', whilst constructivism has been referred to as 'relativism'. This is because realities are considered to be 'apprehendable in the form of multiple, intangible mental constructions, socially and experientially based, local and specific in nature' (Guba & Lincoln, 1994, p. 110). Compared with positivists and post-positivists, who posit that there is a true reality to be discovered or a flawed approximation of one, constructionists argue that there are no absolute truths. Neither is there one construction that is more or less true than any other. Reality is constructed, and according to this paradigm, it is also alterable and may be more or less informed. This notion creates a number of associated 'realities'. Within the constructivist framework, the aim is not to generalise truths from one sample to a larger population; rather, the methodology is hermeneutical and relies on interpretation (Lincoln et al., 2011).[1]

In comparison, the original STIL project was anchored in a post-positivist view of research with the aim of measuring the effect of STT through a quasi-experiment. Some of these perspectives are still evident in this thesis as descriptive

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[1] Parts of this paragraph was developed in an exam paper for a PhD course on Theory of Science, Methodology and Ethics, submitted in May 2019.

measures, such as the inclusion of pupils' results on the spelling test and the national test in reading in Article 3 and the aim of the STIL project being similar to the research aim of Article 1. The main difference is that Article 1 considers previous international research, whereas the original STIL study aimed to measure the effects of introducing STT in a Norwegian context. Given that a quasi-experimental study was not possible due to the COVID-19 pandemic, the research aims and methods were altered. Moving from a quasi-experiment to an exploratory study, the project shifted towards a qualitative approach and a constructivist research paradigm. Data analyses were influenced by several established theories on technology, writing and writing difficulties, and these constructs further influenced the analyses, discussions and dissemination of findings. Within the constructivist research paradigm, I have employed an interpretivist approach, which aims to provide an in-depth understanding of the experiences of specific individuals in a specific context through exploratory studies (Alharahsheh & Pius, 2020). This is in line with the aim and scope of Articles 2 and 3 in this thesis, which respectively explore the experiences of teachers and pupils with writing difficulties (specific individuals) with STT in a Norwegian lower secondary education context (specific context).

3.4 Data Collection

3.4.1 Recruitment and Implementation

The school was recruited through its participation in an online course developed by Statped and the UiA that addressed theoretical and practical approaches to using AT in an inclusive learning environment. In the online course, the teachers were introduced to STT through webinars, instructional videos and online assignments. Instructors from Statped held introductory courses for all teachers (60 minutes) and pupils (45 minutes) at the schools one week prior to the implementation of the technology. As most of the teachers had little experience in using STT, they were encouraged to test it out during various writing activities and were encouraged to contact Statped if they had any technical or pedagogical questions. A week prior to the introduction of STT, the teachers were asked to fill out lesson plans for the following 12 weeks. The teachers took part in the planning process and were asked to make recommendations regarding how STT was to be introduced in the classroom. In the lesson plans, the teachers were asked to describe writing activities, subjects, topics and the duration of the activities. They decided to introduce STT during writing activities in the subjects Language Arts (Norwegian), English, Social Sciences and Natural Sciences. They argued that these were writing-intensive subjects wherein pupils were often required to elaborate on a variety of topics and produce texts with a more advanced vocabulary and grammar, compared with the practical and aesthetic subjects (e.g. Physical Education and Art and Crafts). During the 12-week period, the teachers were also encouraged to provide brief descriptions

of how they experienced each writing session. They commented on their lesson plans using the school's digital learning management system, 'Showbie'. Examples of lesson plans are provided in Article 2.

3.4.2 Participants and Selection Criteria

There were 52 pupils (of a total 92) and 6 teachers (of a total 14) who joined the project. Among the pupils, there were 26 girls and 26 boys whose ages ranged from 13.2 to 16.0 years old (mean age: 14.5 years) and were distributed among Grade 8 (n=19), Grade 9 (n=20) and Grade 10 (n=13). The school was strategically selected as one of three lower secondary schools that took part in the online course on AT. Out of 14 full-time employed teachers who were invited to take part, six teachers agreed. The school decided that they only wanted full-time employees to participate in the study, and one of the reasons was that they had difficulty finding substitute teachers and therefore needed part-time teachers to fill in vacancies. The teachers who took part in the study had to be willing to introduce STT to all pupils during writing activities. The 52 pupils were important contributors to the empirical data in Article 2, although they were not directly described as participants in the article. The participants referred to in Article 2 were the 6 teachers, including the assistant principal who also worked as a teacher. Demographic information for the group of teachers is presented in Table 2.

Table 2. Demographic Information: Teachers

	Gender	Teaching Experience	Subjects using STT	Grade	Position
Teacher 1	Male	> 5 years	Language Arts, English,	8	Teacher, IT Counsellor
Teacher 2	Male	< 20 years	Language Arts, English, Social Sciences	8	Teacher, Assistant Principal
Teacher 3	Female	5–15 years	Language Arts, English, Natural Sciences	8	Teacher
Teacher 4	Female	5–15 years	English, Social Sciences	9	Teacher, Reading Counsellor
Teacher 5	Female	< 20 years	Language Arts, English	9	Teacher
Teacher 6	Male	> 5 years	Natural Sciences	10	Teacher

The 6 pupils who were recruited for Article 3 were considered to have writing difficulties, based on teacher nominations and their performances on two

standardised reading and writing tests. They all performed in the lower levels (level 1 or 2 of 5) of the national reading test for Grade 8 and scored under the 30th percentile on a standardised Norwegian spelling test (Skaathun, 2013). It is likely that pupils who have difficulty with reading also experience writing difficulties as the skill domains underlying writing and reading are closely related (Fitzgerald & Shanahan, 2000; Wengelin & Arfé, 2017). Demographic information on the group of 6 pupils who comprised the sample for Article 3 is presented in Table 3.

Table 3. Demographic Information: Pupils

	Gender	Age (y;m)	Grade	Identified learning disability
Pupil 1	Female	15;5	*10*	General learning disability
Pupil 2	Male	14;1	*9*	Dyslexia
Pupil 3	Female	14;11	*10*	Under assessment for dyslexia
Pupil 4	Female	14;3	*9*	Under assessment for dyslexia
Pupil 5	Male	15;7	*10*	No
Pupil 6	Male	15;8	*10*	No

3.4.4 STT Technology

The computer software analysed in this thesis is the integrated STT feature in Microsoft Office Word 2019 and on Apple's iPad Air 2. The preferred language was automatically set to Norwegian. During the implementation of STT in the first quarter of 2020, all pupils at the school were introduced to STT on iPads. The software decision was made in collaboration with the school leaders who took part in the planning of the intervention. The iPad was considered the most available technology to the pupils and teachers at the time. The researchers provided all pupils at the school with noise-reducing headphones (Jabra Evolve 40 with microphone) and iPad covers with integrated Bluetooth keyboards (ZAGG Rugged Book). In the stimulated recall study conducted in the fall of 2020 (for Article 3), the pupils used STT software integrated into Microsoft Office Word 2019 on laptops. Initially, the plan was to conduct this study on iPads as well, but as it was not possible to enable screen and audio recording whilst using STT, the pupils had to produce text on their laptops. Other kinds of STT software were considered for the study, such as Tuva by Omilion and Dragon Speak by Nuance®. However, these were not chosen as they were not available to all pupils in secondary education and have expensive licence fees. Integrated Norwegian STT software is quite a recent feature and has been available on Apple devices from 2015 and in Microsoft Office software from 2019. It is important to note that the findings presented in this dissertation are based on

this specific STT technology, as well as the features available from Apple and Microsoft at the time of the study (spring and fall of 2020).

3.5 Reliability, Validity and Trustworthiness

The following chapter describes the measures taken to provide reliable and valid research findings and to ensure the dissemination of the results in each article. Qualitative and quantitative researchers often use different terminologies regarding validity and reliability (Cresswell, 2014). The two terms originate from quantitative research, in which 'validity' describes whether a test or scale is able to measure what it aims to measure, and 'reliability' refers to the consistency of the measure. In qualitative research, the term 'trustworthiness' is often applied to describe elements such as the systematic rigour of the research design, the applicability of the research methods and the believability of the findings (Rose & Johnson, 2020). As the present study employs both quantitative and qualitative methods and analyses, examples will be provided of how validity, reliability and trustworthiness have been taken into consideration.

3.5.1 Article 1: Scoping Review on the Use of STT for Adolescents with Learning Difficulties in Secondary Education

The methodological approach chosen for Article 1 was to conduct a scoping review. The aim of such a review is to assess the size and scope of available research and identify the nature and extent of evidence on a specific topic (Grant & Booth, 2009). The review approach originated in health care sciences with an ambition to provide an overview of the most efficient, evidence-based medical practices and procedures. Today, reviews are conducted within most fields of research, including education. There are several kinds of review approaches, and these are distinguished by their approaches to search, appraisal, synthesis and analysis. For example, in a meta-analysis, the results of quantitative studies are combined and analysed statistically to provide effect measures, whereas a critical review aims to identify central concepts, evaluate the quality of existing research literature and derive new theories (Grant & Booth, 2009). Tricco et al. (2018) describe scoping reviews as a type of knowledge synthesis that follows a systematic approach to map evidence on a topic and identify the main concepts, theories, sources and knowledge gaps. In contrast to systematic reviews, scoping reviews may include grey literature (e.g. government reports, policy papers, conference proceeding and pre-printed articles) and ongoing research.

 In this study, a scoping review was conducted as very little previous research was found on the use of STT technology for learners with learning difficulties in secondary education. Thus, it was considered important to provide an overview of the existing literature and describe the aims, scopes, methodological approaches, findings and gaps in current research. The review followed the PRISMA guidelines

for scoping reviews developed by Tricco and colleagues (2018). The guidelines provide a checklist with specific objectives to ensure that the review process is systematic and transparent. The checklist items included several objectives, such as providing eligibility criteria, questions and objectives addressed, as well as a full electronic search strategy from at least one database (Tricco et al., 2018, p. 471). The scoping review includes a PRISMA flow diagram (Page et al., 2021) that illustrates the screening process for peer-reviewed articles. The flow chart shows the total number of identified articles (n=2380), articles included after screening the titles and abstracts (n=79) and articles included after conducting full-text assessment for eligibility (n=8).

3.5.2 Article 2: Qualitative Study of Speech-to-Text Technology as an Inclusive Approach: Lower Secondary Teachers' Experiences

The data materials for Article 2 were collected in three phases, four weeks prior to the introduction of STT (Phase 1), during the 12-week period (Phase 2) and eight months after STT was introduced in the classroom (Phase 3). In Phase 1, the teachers were interviewed in pairs (focus groups). The third phase of data collection was originally planned to be conducted directly after the 12-week period. However, as schools were closed due to the COVID-19 pandemic, we were unable to conduct individual interviews until the following semester. A methodological approach known as triangulation was employed to ensure the trustworthiness of the analyses. Methodological triangulation entails the process of corroborating data from different individuals, types of data and data collection methods (Cresswell, 2014). The six teachers with experiences from six classrooms comprised the different individuals, whilst different types of data were collected through three methodological approaches: observations, focus group interviews and document analyses of lesson plans. When analysing the findings, both deductive and inductive approaches were applied. First, a theory-driven deductive analysis of the data materials was conducted, in which the findings were categorised according to Göransson and Nilholm's (2014) hierarchy of definitions of inclusion. Second, a more inductive approach was taken to explore the main themes and topics presented in the data materials regarding STT's potential as an inclusive approach. Through the inductive approach, prominent topics were identified as categories, including *pupil acceptance*, *curricular content*, *assignments*, *opportunities for collaboration* and *challenges to inclusion*.

3.5.3 Article 3: An Exploratory Study on the Use of Speech-to-Text Technology as a Writing Modality for Pupils with Low Writing Achievement in Norwegian Lower Secondary Education

A research assistant and the author separately coded the video materials obtained for Article 3. Variables that could describe patterns in the pupils' text production were registered from the screen recordings. These include accuracy and the numbers of words produced with STT, words typed, words removed and words typed and spoken per minute. To improve the reliability of the quantitative analyses, the statistical measure of inter-rater reliability (IRR) was calculated using Cohen's kappa. IRR measures the extent to which two raters assign the same score to the same variable. Agreement is often measured in Cohen's kappa, which is a coefficient measure that includes the element of chance and provides a number representing agreement between -1 and +1 (Carletta, 1996). Values higher than 0.75 represent excellent agreement, values between 0.40 and 0.75 represent fair to good agreement and values lower than 0.40 represent poor agreement (Banerjee et al., 1999, p. 6). When comparing the coding material using IRR, all variables were between 0.70 and 1.00, thus representing good to excellent agreement between the raters.

Both deductive and inductive approaches were applied when analysing the qualitative data material for Article 3. The deductive approach applied in this thesis included consulting previous research (e.g. Noakes, 2019; Quinlan, 2004: Leijten & Van Waes, 2005) to consider variables and categories applied in previous studies on the use of STT. For example, some of the error categories employed in Article 3 were deduced from the study by Leijten and Van Waes (2005). However, most categories or variables employed in earlier studies were inapplicable for this thesis because those studies had different theoretical perspectives, research aims, samples or data materials. For example, Noakes (2019) employed measures labelled 'words spelled correctly' and 'correct writing sequences', which were relevant to the study's aim of comparing pupil texts produced with different modalities (handwriting and STT). However, these measures were not specific enough for the analysis for Article 3 of the current study, which aimed to analyse patterns of composition that emerged during text production and pupils' experiences of writing with STT.

3.5 Ethical Considerations

Guidelines and recommendations from the Norwegian Centre for Research Data were followed during the planning, implementation and dissemination phases of the studies. Prior to implementation, both teachers and pupils were informed of the research aims and what their participation would entail. They were informed that participation was voluntary and that they did not have to explain why they did not

want to take part in the study. They were also informed that declining participation would not have any negative consequences. All participants signed a consent form and were informed that they could withdraw their consent at any time until the findings were disseminated. As all pupils were between 13 and 16 years old, parents or guardians had to agree to their participation and sign a consent form.

The teachers reorganised the classrooms during these brief periods of data collection. The pupils were divided into two groups: pupils who took part in the study and those who did not. The students were aware of the reason for this change. Both groups received the same assignments and teaching materials, but only the group who had consented to take part in the study was seated in classrooms with sound and video recorders. The anonymity of the participants was secured by not using the name of the school, pupils or educational staff at any time during the dissemination of the project's findings. All data containing personal information, such as names, voices or faces, were stored in TSD (Services for Sensitive Data[2]), a digital service for the storage of sensitive data in compliance with Norwegian privacy regulations.

According to the Norwegian Guidelines for Research Ethics in the Social Sciences and the Humanities (NESH, 2022, p. 29), '[r]esearchers must protect the integrity and interests of disadvantaged and vulnerable groups'. The sample for Article 3, adolescents with writing difficulties, is likely to be considered a disadvantaged and vulnerable group. The aim of this project is to balance the two aspects described in the ethical guidelines: to protect the integrity and interests of pupils with writing difficulties. The best approach to protect vulnerable groups may appear to be to not invite them to participate in studies in which they are exposed to tests and interviews. However, it is also highlighted in the guidelines that researchers have a social responsibility to gain insights into and develop knowledge about members of vulnerable groups because excessive protection might result in their perspectives being excluded, and society may not gain knowledge on such important topics (NESH, 2022). The importance of research and knowledge regarding writing difficulties became evident during data collection as the researchers discovered that some of the pupils had more severe writing difficulties than their teachers earlier assessed. In particular, four pupils were referred for further assessment for dyslexia as a result of taking part in the study.

As the project was introduced to the teachers, parents and pupils, the researchers emphasised that we wanted all pupils to take part in the study (for Article 2). Some pupils and parents were informed that they were invited to an additional study (Article 3) based on each pupil's performance on the national reading test and the spelling test. Both pupils and parents had to consent to

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[2] In Norwegian «Tjenester for Sensitive Data».

participate, and the teachers were asked whether they considered the pupils with writing difficulties to be eligible for the study. Some pupils did not want to participate, and some parents did not want their children to take part in the study. The teachers also recommended that some pupils not join the study. These recommendations were followed. Furthermore, pupils, parents and teachers were not required to provide their reasons as to why they did not agree to participation. Thus, this information was not obtained.

As this project received public funding from the Norwegian Research Council, the researchers followed the national goals and guidelines for open access to research articles (Norwegian Ministry of Education, 2017). All three articles were submitted to open-access journals to ensure that dissemination of findings would be publicly available. In line with the shift towards more open and accessible science, the project also made a data management plan (DMP). The core elements of a DMP include data descriptions; considerations of how the data may be re-used; documentation of data quality, metadata, storage and backup during the research process; and legal and ethical considerations regarding the sharing and storage of data (Science Europe, 2021).

4 Results

In the following section, the main findings from Articles 1, 2 and 3 are presented with a focus on the overarching research question: *What potential lies in STT technology as a writing tool for pupils with writing difficulties?*

4.1 Article 1: *A Scoping Review on the Use of Speech-to-Text Technology for Adolescents with Learning Difficulties in Secondary Education*

The main objective of Article 1 was to identify and describe existing research on pupils with learning difficulties in lower secondary education regarding their use of STT. Furthermore, this article identified the aims, methodological approaches and major findings of empirical studies published between January 2000 and April 2022. Article 1 results show that very little robust research has been conducted on the use of STT among pupils with learning difficulties in lower secondary education. Through the scoping review process, eight peer-reviewed articles and five publications of grey literature were identified. The methodological designs of the peer-reviewed studies were experimental (2), quasi-experimental (3) and explorative (3). The grey literature comprised one quasi-experimental study and three explorative studies. The variety of designs provides different opportunities to draw conclusions from the analysed studies on the potential of STT technology as a writing tool. According to a methodological hierarchy for quantitative methods (Davies et al., 2000), the experimental design can provide more robust evidence of effectiveness compared with quasi-experimental designs, which in turn are more robust than non-experimental designs. Additionally, grey literature generally has a lower scientific value as it has not undergone quality assessment through the peer review process. Therefore, the findings reported in the grey literature are deemed less reliable compared with the results from the peer-reviewed studies and are given less emphasis in the following presentation of the results from Article 1.

The analyses of the peer-reviewed articles demonstrated which aspects of writing were investigated in the eight studies examined. Five main areas of interest were identified: (1) STT's influence on writing-related skills, (2) text assessment, (3) writing processes, (4) accuracy of the technology and (5) participants' experiences of producing text with STT. The explorative studies only investigated the participants' experiences, the quasi-experimental studies mainly assessed pupil texts and writing processes and the experimental studies analysed STT's effect on writing-related skills. Spelling is the only specific writing skill measured in the experimental studies of STT, and it is only measured in a single study (i.e. Higgins & Raskind, 2000). The other measures of skills in the experimental studies are termed *writing-related* skills and refer to measures of underlying cognitive processes influencing both reading and writing (e.g. metacognitive ability and short-term memory).

Higgins and Raskind (2000) found that STT could potentially be used to improve reading comprehension, word recognition and spelling among students with learning difficulties. On the other hand, a study by Svensson et al. (2021) showed improvements in pupils' reading skills and in their reported motivation towards reading and writing after using several kinds of AT, of which STT was one. However, Svensson et al. (2021) also concluded that pupils' ability to communicate text (writing skills) was generally difficult to measure. In the three quasi-experimental studies, MacArthur and Cavalier (2004) found that STT helped students with learning difficulties to produce essays with better text quality. Quinlan (2004) reported that STT significantly improved text length and reduced the number of errors in texts by pupils with learning difficulties. Noakes (2019) found that pupils with learning difficulties significantly increased their text length, number of words spelled correctly and number of correct writing sequences when writing with STT. Overall, these findings suggest that STT has the potential to improve texts for pupils with writing difficulties in lower secondary education. However, the scoping review concludes that both the quantity and the quality of research investigating the use of STT among adolescents with writing difficulties are insufficient to make strong recommendations for educational practice. Nevertheless, the explorative studies provide valuable insights into the potential of introducing STT in the secondary classroom as they explore how the technology has been experienced by pupils, parents and teachers.

Ok et al. (2020) reported that pupils had positive perceptions of writing with STT, and younger pupils (ages 9–10) tended to use it more often than older ones (ages 13–14). Nordström et al. (2019) also explored the potential of STT for different age groups, and reported findings similar to those of Ok et al. (2020). In particular, Nordström et al. (2019) found that the younger pupils (ages 9–10) continued, to a larger extent, to use the technology after the intervention compared with the older pupils (ages 14–18). Based on their findings, Ok et al. (2020) highlighted the importance of considering student variability when it comes to the potential of introducing STT, as some pupils are likely to benefit and adapt to using the technology. These findings are supported by the explorative studies by Jeffs et al. (2005) and Nordström et al. (2019). All three studies stress the need to provide support and training when introducing STT to pupils with writing difficulties in secondary education.

Finally, the scoping review revealed that existing research has primarily focused on the potential of STT as an AT rather than an instructional technology. Edyburn (2006) argues that the distinction between considering STT as primarily an assistive or instructional technology lies in the aim and purpose of introducing the technology, that is, instructional writing technology aims to improve reading and writing-related skills across modalities, whilst the purpose of AT is to compensate

for the lack of writing skills and enable pupils to produce higher quality texts. Only the experimental studies investigated the potential of STT as an instructional technology, whereas the quasi-experimental and explorative studies considered the assistive potential of the technology. The scoping review's findings suggest that there is potential for STT as both an assistive and instructional technology. However, the research base is limited and thus far relies only on studies conducted with pupils speaking and writing in English or Swedish.

4.2 Article 2: *Speech-to-Text Technology as an Inclusive Approach: Lower Secondary Teachers' Experiences*

Article 2 explores the potential of STT as an inclusive approach in lower secondary education. According to the teachers who participated in this study, there were both benefits and challenges to introducing STT as an inclusive approach. In particular, they reported that the main academic benefits of STT is the opportunity for pupils to discuss conventions of spoken and written language, make drafts using oral skills and acquire a new approach to learning, whilst a social benefit was that all pupils could take part in the same writing activities to a larger extent. Some of the constraints described by the teachers was that most pupils had already acquired efficient handwriting and typing skills; therefore, they were hesitant to spend time introducing a new approach to writing when only the pupils with writing difficulties were likely to have an actual benefit from using STT as a transcription aid.

As described in the theory section, Göransson and Nilholm (2014) present a hierarchy of definitions of inclusion. This hierarchy was employed when analysing the findings for Article 2. Thus, the teachers' experiences and reflections on the potential of STT in lower secondary education were evaluated in relation to different understandings of inclusion. Category A definitions describe inclusion as the placement of pupils with disabilities or pupils in need of special support in general education classrooms (Göransson & Nilholm, 2014). Given that the teachers agreed to introduce STT to all pupils in a whole-class setting as a premise for participation in the study, Category A interpretations were not prominent in Article 2. However, when the teachers shared their experiences of introducing STT in a whole-class environment, they noted that pupils could benefit from writing in remote locations, as this was likely to reduce their experiences of disturbance and embarrassment. Whilst this is an argument against introducing STT in a whole-class environment, it does not necessarily regard the placement of pupils with special educational needs or disabilities.

The Category B definition of inclusion (Göransson & Nilholm, 2014) considers STT's potential to meet the academic and social needs of pupils with difficulties. The teachers highlighted that they saw the largest academic potential for

pupils with writing difficulties, as they were allowed to use STT on formal exams and were considered to benefit the most from STT as a spelling and drafting aid. One teacher highlighted a previous experience with a pupil with dyslexia who was previously unable to produce readable texts in English (as a foreign language) whilst typing or writing by hand. The teacher introduced the pupil to STT during the first year of secondary education and argued that this enabled the pupil to pass the final exam in English two years later. The results from Article 2 show that several teachers considered STT especially helpful for pupils who struggled to compose texts in foreign languages. They argued that such pupils often experience a gap between what they can convey orally and in writing.

Meanwhile, the social benefit of introducing STT to pupils with difficulties was described as the opportunity to take part in more of the writing activities that took place in the lower secondary classroom. The teachers remarked that some of the pupils with writing difficulties did not want to continue using STT if they were the only ones who would be using this technology. Another barrier described by the teachers was that some secondary pupils with writing difficulties appeared to be less motivated to try out a new approach to writing than their peers without writing difficulties. The teachers described the pupils as less motivated to try another approach to writing and more frustrated when the STT technology was inaccurate.

The potential of STT as an inclusive approach according to a Category C definition was also explored in Article 2. The findings described both the benefits and constraints when STT was introduced to meet the academic and social needs of all pupils in the secondary classroom. Some of the teachers were critical of the academic potential of STT for all pupils because it was not available to all pupils as a writing approach during the final exams. Only those with a documented need for accommodations are currently allowed to use STT technology during formal exams in Norwegian secondary education.

Another constraint was that most pupils had already acquired efficient handwriting and typing skills. Thus, the teachers recommended introducing STT to pupils prior to secondary education, such as during Grades 5–7 (ages 10–12), to make this approach a genuine alternative to typing or handwriting. Regarding the potential of STTs to meet the social needs of all pupils, the findings from Article 2 showed that one benefit described by the teachers was that STT provided new opportunities for collaboration. Some of the informants described how they organised writing tasks in different phases when writing with STT, which encouraged the pupils to collaborate and produce drafts together. During the drafting, the teachers observed that their pupils were actively taking part in text production, including those who often struggled to produce text on their own. The teachers also described a reduced barrier as all pupils were able to speak to the computer and could contribute to the completion of the collaborative tasks. Being

allowed to collaborate and use STT was considered a social and academic benefit by the teachers, as the pupils could contribute to and discuss the content and structure of a draft before they revised and finalised their assignments independently. Embarrassment and hesitation to speak out loud were two of the constraints highlighted by the teachers who evaluated the introduction of STT during writing activities in a whole-class environment.

According to the final category, Category D, inclusion is defined as creating mindsets and communities that value diversity, justice, equity and subjugated knowledge (Göransson & Nilholm, 2014). To analyse the potential of STT according to a Category D definition of inclusion is an ambitious undertaking that is not entirely feasible within the scope of Article 2. However, the teachers commented on the topic, for example, when they noted that STT had the potential to alter their opinions about writing and how writing activities were to be conducted. The teachers saw STT as a tool that could provide more pupils with an opportunity to participate in writing activities. In turn, by increasing pupils' participation in and access to writing, STT may contribute to creating more inclusive learning communities that value diversity. Whilst STT alone cannot create more accepting, diverse and inclusive learning environments, it may alter ideas of what writing should be in an educational context and increase acceptance of alternatives, provided that pupils are introduced to the technology at an appropriate stage in their development. In terms of increasing access to writing, by changing the opinions of how pupils are allowed to produce text, STT may become not just an assistive technology but an alternative writing technology that is available to all pupils. In particular, if STT is introduced as an alternative for all pupils, it is not seen as a tool only for students with disabilities, which may reduce stigma. Altering the opinions of teachers, pupils and parents may be part of a process that can create a more tolerant society, where text can be produced in alternative manners.

4.3 Article 3: *An Exploratory Study on the use of Speech-to-Text Technology as a Writing Modality for Pupils With low Writing Achievement in Norwegian Lower Secondary Education*

Relating the overarching research question of this thesis to the third article, the aim of Article 3 is to explore the potential of STT as a writing modality for pupils with low writing achievement in Norwegian lower secondary education. Furthermore, Article 3 provides findings on six pupils' experiences of using STT to produce a reflective text about social media's influence on adolescents. The pupils reported that it was exciting to try a new writing approach and that they were all able to produce a reflective text using STT. Some of the pupils considered STT a spelling aid, and some reported that it was easier to elaborate on a topic whilst speaking compared to when they were typing or writing by hand.

However, Article 3 also concludes that although STT has potential, it is not yet a consistently suitable writing technology for pupils with writing difficulties in the context of Norwegian lower secondary education. This is mainly due to accuracy issues and prominent transcription errors. In particular, when accuracy was analysed in Article 3, two measures were applied. The first measure compared what the pupils said to what the STT technology transcribed, thus measuring the accuracy of the technology. In comparison, the second accuracy measure considered the number of errors in the submitted texts, making it a text-quality measure. The first measure of STT accuracy ranged from 70% to 85%. Compared with earlier studies on the use of STT, the STT accuracy measured in Article 3 was slightly lower than the mean accuracy of 87% measured by MacArthur and Cavalier (2004) almost 20 years ago among 31 American high school students with and without learning difficulties. In a more recent Canadian study of 45 Grade 5 pupils (ages 10–11) without learning difficulties, Haug and Klein (2018) reported that all pupils had an STT accuracy above 80%. The researchers concluded that STT software is currently 'accurate enough at recognizing the speech of mid-elementary, native English speakers [and] that they produce fewer transcription errors than the students would produce in handwriting' (Haug & Klein, 2018, p. 59). Yet, in an American exploratory study of 341 students from Grades 4–8 (Ok et al., 2020), one of the main findings was that 67% of students across all grades responded that inaccuracy was the main challenge they encountered in using STT.

The abovementioned finding is supported in Article 3 through the analyses of both pupil interviews and screen recordings. In particular, the analyses of screen recordings revealed that each pupil experienced between 23 and 36 transcription errors during the 15-minute writing sessions. Examples of registered transcription errors were the transcription of homonyms or similar sounding words, misspelled words, words from other languages, words that were not transcribed and transcriptions of words or sounds that were not spoken. However, after the pupils revised their texts, final text accuracy (lack of errors) ranged from 92% to 97%, except for one pupil who had a final accuracy of 75%. The pupil reported during the subsequent interview that he did not make revisions because he wanted the researchers to see the mistakes the STT technology made. As for all other pupils, they stated that the main challenges when writing with STT was that they had to revise their text often, that it was embarrassing to speak out loud and that they had to alter their dialect to a more standard dialect to obtain higher accuracy.

Embarrassment relates to environmental factors that influence writing, as described by Graham in the WWC model. Graham (2018) highlights that writing communities, such as learning environments in classrooms, are not static entities, and that relationships between students and those between teachers and students

tend to fluctuate across situations and time. Even though all the pupils in the current study were writing simultaneously, they were not just concerned with their own text but were also influenced by their peers' reactions to what they were writing. One of the pupils said that it would not have been embarrassing if she could use STT in a room with only her close friends. Thus, the learning environment appears to play an important role when the text is produced out loud. Thus, the technology's potential may be influenced by how secure the pupil feels in the learning environment.

Of the six pupils included in the study for Article 3, two had identified LDs. One pupil was diagnosed with specific reading and writing disorder dyslexia, whilst the other had a general learning disability. Analyses of video recordings showed that these two pupils with identified LDs expressed greater frustration during the writing process compared with the other pupils. This is in line with Graham's (2018) perspective in the WWC model, in which he argues that previous experiences with writing are likely to influence the other components involved in writing and, therefore, a writer's capabilities.

5 Discussion

This dissertation is the first to explore the use of STT for pupils with writing difficulties in Norwegian lower secondary education. It posts the overarching research question: '*What potential lies in STT technology as a writing tool for pupils with writing difficulties?*' This study's findings reveal that STT may aid in transcription and increase the capabilities of pupils with writing difficulties in lower secondary education by allowing them to produce written texts using oral skills. However, the results also show that STT is currently not a reliable spelling aid in Norwegian, as it produces several transcription errors and requires pupils to adapt to highly frequent dialects to improve accuracy. When considering STT as an inclusive approach, the teachers find it easier to argue for the social benefits of introducing all pupils to STT compared with supporting the academic benefits for all. As most pupils have already acquired sufficient writing strategies by lower secondary education, the teachers primarily see it as an AT for pupils who struggle with transcription or motivation towards writing. Indeed, perspectives on what writing should be in lower secondary education influence the potential of STT for pupils with writing difficulties. This will be discussed further in the following chapter.

5.1 The Potential of STT Technology for Pupils with Writing Difficulties

STT's potential to help pupils with writing difficulties is influenced by several factors, including the learning environment, the goal of a task, the content of a task and the consequences of failing or succeeding with a task. That writing is an interaction between tools, actions, goals and written products (Graham, 2018) became evident when studying the potential of replacing one writing modality with another. Graham (2018) describes writing as a complex activity influenced by several elements, such as emotions, personality traits, physical states, control mechanisms, memory and writing communities, and is shaped by skills that influence the capability for transcription, ideation, translation, conceptualisation or re-conceptualisation. Thus, considering the different elements involved in writing, STT's potential varies according to the aspect of writing being measured or described.

In educational practice, there are different aims and arguments behind the introduction of STT to pupils with learning difficulties. Edyburn (2006) emphasises that technology in education may have different roles, such as remediating difficulties and providing tools that compensate for a lack of proficiency. Edyburn (2006, p. 22) further states that educators who plan special education must also consider the aim of introducing AT and the percentage of time and effort that should be devoted to remediation or compensation. The different roles or potentials of AT such as remediation or compensation, which were described to some extent in previous research (Cook & Hussey, 2002; Edyburn, 2006; King 1999), were

identified when analysing previous studies on STT technology for the scoping review. Previous studies have either measured STT's influence on writing-related skills (remediation) or how STT could affect writing capabilities (compensation). The majority of the studies considered STTs' potential as a compensatory technology that aimed to provide pupils with writing difficulties with opportunities to produce higher quality texts, make fewer spelling errors and increase their motivation towards writing. Only two studies (Higgins & Raskind, 2000; Svensson et al., 2021) aimed to measure STTs' potential to remediate writing difficulties by improving their writing-related skills. This shows that there is very little scientific evidence on the potential of STT as a remedial technology.

Researchers (Edyburn, 2015; Svensson, 2021) have highlighted the difficulties involved in measuring the short- and long-term effects of AT, especially its remedial effect on writing skills. Writing is a complex activity that involves not just a single skill but multiple skills, making it difficult for researchers to isolate and measure 'pure' writing skills. Higgins and Raskind's study (2000) was the only one that compared spelling abilities before and after an STT intervention. In particular, they found significant gains for pupils with writing difficulties in spelling and writing-related skills, such as reading comprehension and word recognition. The study by Svensson et al. (2021) regarding STTs' potential as a remedial writing technology was less conclusive. They stated that their instruments, which aimed to measure the communication of text, did not fully capture what they were expected to measure. They also suggested that more research should be conducted to find reliable instruments that can properly investigate whether STT technology may increase the writing abilities of pupils with writing difficulties.

One hypothesis describing STT's potential to help pupils with writing difficulties is that with STT, 'students can (a) generate words more rapidly than typing, (b) bypass challenges of spelling, (c) transcend challenges with short-term memory required to organize and draft text, and (d) express themselves without inhibitions associated with writing accurately or formally' (Ok et al., 2020, p. 2). The majority of studies included in the scoping review had similar hypotheses and aimed to study STT's potential to increase pupils' capabilities to produce text when using the technology. The experimental studies (MacArthur & Cavalier, 2004; Noakes, 2019; Quinlan, 2004) reported that STT had the potential to increase the capabilities of pupils with writing difficulties as they produced longer texts with higher holistic quality, fewer surface errors and more correct writing sequences when comparing texts written with STT and by hand. The explorative studies (Jeffs et al., 2006; Nordström et al., 2019; Ok et al., 2020) found that pupils, parents and teachers all had high levels of acceptability and perceived usability of the STT technology.

In addition, STT has the potential to increase the motivation towards writing of pupils with writing difficulties (Jeffs et al., 2006; MacArthur & Cavalier, 2004; Svensson et al., 2021). Yet, for STT to realise this potential, pupils and teachers require environmental support, device support and instructional support (Ok et al., 2020). Examples of environmental support include providing a safe learning environment for speaking out loud, a stable Internet connection and quiet areas where pupils will not be interrupted whilst dictating. Device support is exemplified by appropriate hardware (e.g. headphones with microphones) and software with high speech recognition accuracy. Instructional support is described as providing opportunities for pupils to practise verbal skills and learn how to edit, as well as scaffolding for writing and editing, such as checklists and prompts. From the previous studies on the potential of STT technology to help pupils with writing difficulties at the secondary education level, it is evident that writing truly is a complex activity and that the consequences of replacing one writing modality with another both influence and are influenced by a number of elements involved in writing, including writing-related skills, writing strategies and the learning environment.

The results of the three articles show that, overall, the potential of STT depends on the purpose of introducing the technology. By analysing the findings in the three articles and building on Edyburn's (2006) distinction between remedial and compensatory technologies, this explorative study identified four purposes of introducing STT in the secondary classroom (Table 4).

Table 4. Four Purposes of Introducing STT in the Secondary Classroom

	Aims to:
Remedial technology	Develop general writing skills for pupils with writing difficulties
Compensatory technology	Provide capabilities during writing activities for pupils with writing difficulties
Instructional technology	Develop general writing skills for all pupils
Alternative technology	Provide capabilities during writing activities for all pupils

These comprise STT as a (1) remedial or (2) instructional technology aimed at improving pupils' writing skills after exposure to STT, which also includes when they are writing by hand or typing, and STT as a (3) compensatory or (4) alternative writing technology that intends to increase pupils' capabilities when they are writing using STT technology.

Furthermore, regarding STT as an inclusive approach, the four categories can be seen in relation to the two target groups. This means that STT's potential varies according to (a) whether it is introduced as a remedial or compensatory technology for pupils with writing difficulties, or (b) as an instructional or alternative technology to improve all pupils' ability to produce written content. In other words, a major finding of this project is that the aim and target group are important factors that impact STT's potential as an approach to writing in lower secondary education. This finding is illustrated in Figure 2, where the four categories can be seen in relation to the two axes of the technology's intended target and aim. It is important to note that the four categories should not be considered mutually exclusive, but rather as elements on a continuum along the two axes. For example, pupils who use STT as a compensatory technology may also experience remediation, even though the original intention was to compensate for their lack of writing proficiency.

Figure 2. The Potential of STT as a Writing Approach in Relation to the Target Groups and Aims
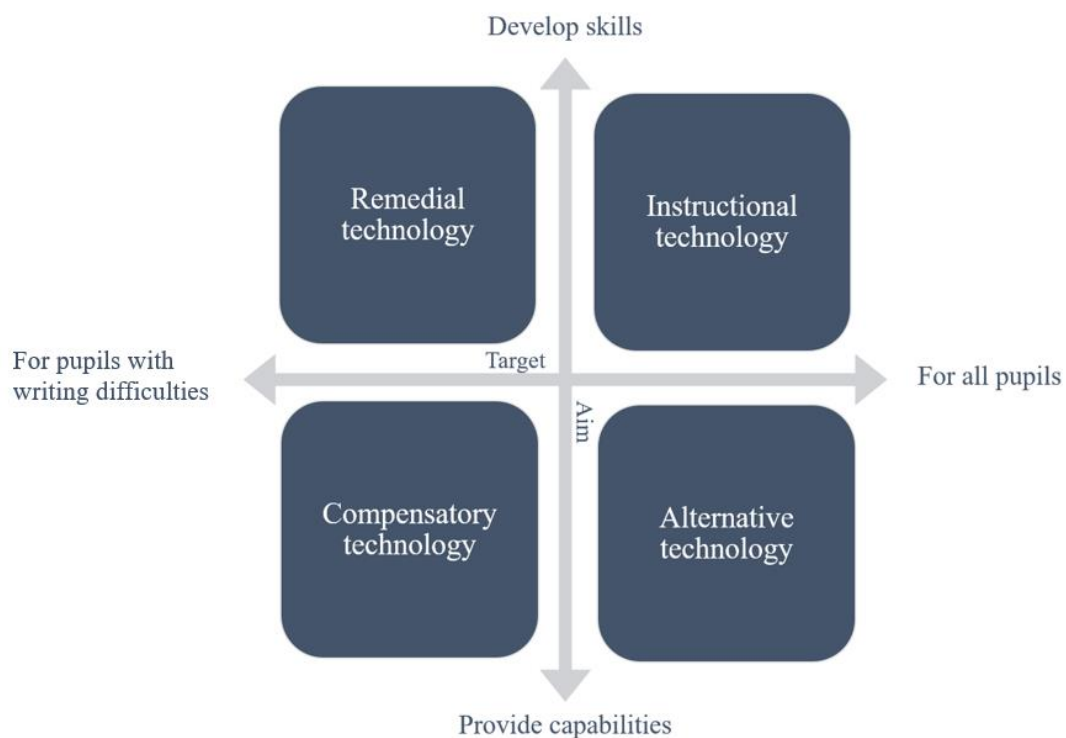
In the following sections, the model shown in Figure 2 is used to discuss how the findings from the three articles contribute to answering the overarching research question on the potential of STT to help pupils with writing difficulties. The axes from the model structure the following discussion, where the following findings are explained: (1) the findings related to the target axis (STT's potential as an inclusive

approach) and (2) the results related to the aim axis (STT's potential to develop pupils' skills or help them acquire capabilities).

5.1.1 Inclusion

One of the axes in the model (Figure 2) relates to the target users of STT and draws a line between educational technology that is used by all pupils (instructional or alternative technology) and AT that is mainly used by pupils with writing difficulties (remedial or compensatory technology). Article 2 of this thesis explores this target axis through teachers' perspectives on STT as an inclusive approach. The findings support the complexity of inclusion, as described by Haug (2017) and Görranson and Nilholm (2014). On the one hand, the teachers considered STT to have academic potential to increase pupils' writing capabilities, as it provides opportunities to effortlessly produce first drafts and retrieve background knowledge when writing about a topic. On the other hand, the teachers considered STT to be most accessible and beneficial for pupils with writing difficulties because they needed a spelling aid and were allowed to use STT during formal exams. Haug (2017) describes a distinction between inclusion as intention and inclusion as practice, arguing that it is almost impossible to be against inclusion as an intention, but that it can be challenging to realise through educational practice. This was supported by the findings in Article 2, wherein the teachers positively viewed the testing of STT to be an inclusive approach, yet they also described the challenges that occurred in a whole-class environment. The teachers reported increased distractions, inaccurate technology, improper use of the technology and pupils that were not motivated to try STT.

The teachers also described several benefits of introducing STT for all pupils. They considered STT as an approach that could reduce barriers to participation by allowing more pupils to take part in writing activities, especially while working on collaborative writing tasks. As Graham (2018) describes, writing tools influence and are influenced by the goals and actions involved in producing a written product. Relating the findings in Article 2 to Graham's WWC model, it appears that STT may have greater potential when the goal is to collaborate or produce written products with input and guidance from peers. In addition, one teacher described how the introduction of STT altered his teaching practice, sharing that he now wanted the pupils to collaborate more during writing activities and saw STT as an opportunity for them to compare and discuss the content and structure of their texts. These ideas are in line with the main tenets underlying Graham's WWC model (2018), which emphasises that pupils increase their capabilities whilst collaborating during writing activities because they gain access to each other's cognitive writing resources.

It was also evident from the findings of this study that STT was not equally accessible to all pupils. Those with rural dialects experienced more transcription

errors compared with pupils who had a more urban (highly prevalent) dialect. Some pupils described that they altered their dialect to improve the accuracy of the STT. That pupils are unable to use their dialect during writing activities is a constraint of the inclusive approach, which, according to the highest level of inclusion described by Göransson and Nilholm (2014), is supposed to make the classroom hospitable to all learners and value diversity. During individual activities, the teachers considered STT to have the greatest academic potential for pupils with writing difficulties. Yet, they also described that pupils with writing difficulties were often hesitant to use AT or other adapted approaches in a whole-class environment if they were the only ones using it. Thus, the teachers saw that, as a group, the pupils would academically benefit from differentiation, yet socially, they would benefit from having the same technology available.

The abovementioned finding demonstrates one of the many dilemmatic aspects of inclusion, which is described as having both academic and a social aspect (Göransson & Nilholm, 2014). One suggestion from the teachers in Article 2 was that STT could be introduced at an earlier age, such as during the latter part of their primary education. Both Ok et al. (2020) and Nordström et al. (2019) found that younger pupils (ages 9–10) held more positive views towards using STT than older pupils (ages 13–14). Ok et al. (2020) suggest that this may be because younger pupils are still developing their writing skills and are not as set in their approaches to writing as their older counterparts. The academic gap is also likely to be smaller during primary education, and there are no high-stakes exams in the Norwegian educational system until secondary education. Thus, these findings indicate that STT may have greater potential as an inclusive approach if it is introduced in the latter part of primary education, rather than in secondary education.

5.1.2 Skills and Capabilities

The other axis in the model (Figure 2) relates to the aim behind introducing pupils to STT and draws a line between improving generalised writing skills (remedial or instructional technology) and increasing writing capabilities when using STT (compensatory or alternative technology). That STT had different aims in a lower secondary education context became clear in the first article. Among the eight peer-reviewed articles, two studies explored STT's potential as a remedial technology, aiming to improve the writing skills of pupils with writing difficulties after being exposed to STT. Higgins and Raskind (2000) and Svensson et al. (2021) employed experimental designs and measured pupils' writing-related skills (e.g. word recognition, spelling and reading comprehension) before and after using STT during writing activities. Higgins and Raskind (2000) found that pupils with writing difficulties had significant gains in reading comprehension, word recognition and spelling when using STT. In comparison, Svensson et al. (2021) had a more

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moderate finding: the intervention group using STT and the comparison group did not have differences in terms of improvements in writing-related skills after one year. Overall, these findings indicate that STT has the potential to become a remedial technology, yet the current knowledge base is very limited, and more research is required to be able to conclude on STTs' potential as a remedial technology.

The aim of introducing STT as a remedial technology is to improve writing skills in general by enabling pupils with writing difficulties to produce more text and increasing their exposure to writing activities (Edyburn, 2006). The articles in this thesis did not aim to measure pupils' writing skills development. Yet, the findings presented in Articles 1 and 2 indicate that there appears to be a gap between the promising potential of STT as a remedial technology described in international empirical research (Higgins & Raskind, 2000; Svensson et al., 2021) and the findings from a Norwegian context presented in Article 3. In particular, the analyses from Article 3 show that pupils using STT in Norwegian may experience lower transcription accuracy than those using STT in English. This may be expected because STT had relatively recently (fall 2019) become available as a dictation tool in Microsoft Office at the time of the study (fall 2020). Furthermore, the learning algorithms underlying STT technology tend to become more accurate when provided with access to large datasets (Bacchiani et al., 2017). Datasets of spoken and written English in a variety of dialects and sociolects are larger and more available compared with Norwegian datasets. Thus, the accuracy of Norwegian STT is likely to improve as more speakers of Norwegian use the technology and contribute to the creation of larger and more representative datasets.

Furthermore, STT technology is not an adapted tool designed specifically for pupils with writing difficulties. Zhao (2009) argues that STT is a platform or a generic tool that can and should be re-adapted in much the same way as printing technology to make it an eligible educational tool. Thus, educators must consider STT's potential to help individual pupils decide how and whether they will actually benefit from text production by speech. The findings from Article 3 suggest that pupils who struggle with encoding may experience a lack of control when producing text with STT because the text often appears at a higher pace than when they type on a keyboard or write by hand. Moreover, students with expressive language difficulties or non-standard accents can become frustrated with STT as they are more likely to experience transcription errors (Ok et al., 2020).

MacArthur (2009) and Kraft (2023) suggest that pupils should receive specific instructions on how to edit text when writing with STT. One approach that may be beneficial for pupils with writing difficulties using STT is to use its reading counterpart, namely, TTS technology. TTS converts written text into digital speech, allowing pupils to listen to what they have written. As pupils with writing

difficulties also often experience reading difficulties (Wengelin & Arfé, 2017), TTS may be helpful when they have to proofread and edit the text they have written. However, the use of TTS will not help with correcting homophone errors, as homophones are words that sound the same but have different meanings and spellings.

The majority of studies included in the scoping review aimed to measure STT's potential as a compensatory or alternative technology with the purpose of measuring or describing how STT may enhance pupils' writing capabilities. These studies described or measured whether STT improved the writing performance of pupils with writing difficulties. The studies either compared how pupils with writing difficulties performed when using STT and when using other writing modalities or they compared how pupils with and without writing difficulties performed when writing with STT. The studies analysed text measures, the writing processes, accuracy of the technology and writing experiences and demonstrated that STT has the potential to increase pupils' capabilities to produce higher-quality texts. For example, MacArthur and Cavalier (2004) and Quinlan (2004) found the potential of STT as a compensatory technology when pupils with writing difficulties showed improved writing performance in terms of longer texts and fewer surface errors than when using STT compared to handwriting. They also found that pupils with writing difficulties produced higher-quality texts when using STT (MacArthur & Cavalier, 2004). Writing performance was measured through text analysis using a 7-point holistic scale that rated ideas, content, organisation, word choice, sentence fluency and conventions.

Article 3 reveals mixed findings regarding STT's potential to increase the capabilities of pupils with writing difficulties to produce argumentative texts in Norwegian. The pupils with writing difficulties described that they experienced both benefits and constraints due to technology during the writing process. The areas where the pupils described increased capability relate primarily to spelling and ideation. They further shared that they could use words that they previously did not know how to spell and gained verbal skills to elaborate on their arguments. They described constraints such as embarrassment, limited opportunities to plan whilst speaking and a great deal of time spent on revisions due to inaccurate transcription. This is in line with a previous finding, which states that teachers are concerned that word processors could place greater cognitive demands on students than when using paper and pen (Williams & Beam, 2019). The findings also contest the hypothesis that STT reduces the constraints of transcription (Arcon et al., 2017) and highlight the notion that the accuracy of the technology is an important factor that determines whether STT is experienced as an actual transcription aid.

The teachers in Article 2 stated that STT had potential as an alternative technology to increase the capabilities of all pupils. For example, the teachers

described how the introduction of STT into the secondary classroom prompted discussions on conventions for oral and written language and enabled pupils to produce first drafts for which they effortlessly retrieved background knowledge. The teachers also observed that the pupils revised their texts more often when they were composed with STT. They considered this a benefit as they encouraged their pupils to make more revisions to improve their texts. Furthermore, some teachers argued that STT could be appropriate in writing-intensive subjects because it facilitated elaborating on ideas and writing them down. These findings indicate that STT has the potential to increase writing capabilities for all pupils and has been identified through Article 2 as an alternative writing technology. However, the results also indicate that the teachers mainly considered STT to be a compensatory technology in secondary education because most pupils had already established a more effective writing approach, and only those with a documented need for assistance were allowed to use STT on formal exams.

STT's potential as an instructional or alternative technology has, to a lesser degree, been explored in this thesis compared with the remedial or compensatory potential described in the model (Figure 2). The main reasons for this are that the overarching research question regarding pupils with writing difficulties and the use of instructional and alternative technologies concerns all pupils. However, the instructional or alternative aspect remains a critical aspect of any discussion on STT's potential as a writing tool for pupils with writing difficulties. Most Norwegian secondary classrooms consist of pupils with and without writing difficulties; thus, if technology is introduced to pupils with writing difficulties, it is likely to influence the entire community of writers, as described by Graham (2018).

5.2 Modes of Functioning

A capabilities approach emphasises the equality of opportunity and describes how pupils may experience reduced barriers if provided with alternative ways to function (Terzi, 2010). If STT's potential is considered according to a social perspective of disabilities (Anastasiou & Kauffman, 2013; Haegele & Hodge, 2016), it may be considered an alternative technology if pupils do not experience difficulties and as a compensatory technology if they experience difficulties. Yet, these experiences are, according to a social perspective, not contextualised in the individual but in a relationship between the individual and the community. Thus, the same pupil can either experience difficulties in a learning environment that does not provide STT technology or become a pupil who does not experience difficulties in an environment that does provide opportunities to use STT. This shows the importance of educators being able to make alternatives available.

Current research on STT in lower secondary education provides a relatively limited perspective on its potential to increase writing-related skills and capabilities

(Matre & Cameron, 2022). Yet, according to the rule of the least dangerous assumption (Donnellan, 1984), educational decisions should be taken with a longer perspective in mind. According to this rule, pupils with writing difficulties should be introduced to STT if educators consider them to be likely to function more independently in the future with such technology. As noted by Graham (2018), the writing community is also important when educators decide when and to what degree different writing modalities should be introduced. Furthermore, educators must also consider the entire community of writers. Pupils without writing difficulties are not as likely to experience the same increase in capabilities with STT because they do not need remediation or compensation to a similar extent. However, as described by the teachers in Article 2 and by Polgar (2011), if pupils with difficulties are the only ones who are allowed to use a specific technical resource, they may not want to use it at all because it is experienced as a stigmatising learning approach. Thus, it could be argued that if pupils with writing disabilities are to experience the potential of STT, the technology should be available to all pupils. In addition, an aspect of inclusion is to create communities that acknowledge diversity (Göransson & Nilholm, 2014). By normalising STT as a writing approach and encouraging pupils to choose and combine writing modalities at home or during school hours, educators can contribute to creating more inclusive and tolerant learning environments.

5.3 Practical Implications

Teachers and school leaders are regularly exposed to new approaches. However, given the limited research on the use of STT in educational contexts (Matre & Cameron, 2022; Perelmutter, 2017), teaching professionals are faced with a difficult task when deciding whether STT should be introduced as a writing approach in secondary education classrooms. The results indicate that from an inclusion perspective, it is easier to argue for the social benefits of introducing STT to all pupils than the academic benefits of introducing the technology to them. The findings suggest that teachers consider STT to have the potential to increase the writing capabilities of all pupils, but that it is a more applicable goal for pupils with writing difficulties. This is explained by the need for and the right to have assistive aid, which are more prominent for pupils with writing difficulties. As most pupils will benefit from having an alternative approach to writing, such as when they are faced with writer's block or want to elaborate on a topic orally or create a first draft without having to worry about spelling, STT may be a useful alternative for all pupils in certain contexts. However, for pupils with writing difficulties, the present study shows that Norwegian STT needs to develop further before teachers can introduce it as an entirely accurate and reliable writing approach for pupils who struggle with spelling.

Teachers need to justify why they spend valuable time introducing a new writing approach, such as STT, if pupils already have sufficient writing skills and strategies. Yet, they must also justify why an approach to writing that may benefit some pupils has not been introduced. The biggest dilemma from an inclusive perspective is that if teachers decide to only introduce STT to pupils with writing difficulties, they may create segregating writing practices that pupils with difficulties could be hesitant to use. STT technology is still relatively young, and both the theoretical and practical implications of introducing this technology in a classroom must be further explored so that teaching professionals can make reliable predictions about STT's potential as a writing modality for pupils with writing difficulties. Regarding skills versus capabilities, this thesis does not measure whether pupils (with disabilities) develop specific writing skills more efficiently than others when using STT. However, it does describe some of the capabilities STT may provide in lower secondary education, such as reducing the barriers of transcription and providing pupils with an alternative writing approach when they want to elaborate on a topic or, contrarily, if they experience writer's block.

Moreover, according to the teachers in this study, STT is of greater benefit to pupils with writing difficulties than to those who do not need assistance with transcription. Both because the pupils with writing difficulties are the ones who are in need of assistance and because they are allowed to use it during exams. Therefore, the teachers described that they found it easier to justify spending time introducing STT to pupils with difficulties compared with their peers who did not have a documented need or entitlement to use STT during exams. Finally, to make STT an inclusive approach that could improve the social and academic capabilities of all pupils, the teachers recommended that it should be introduced prior to secondary education.

5.4 Limitations and Implications for Future Research

The original intention of this project was to conduct an experimental study to measure the effects of introducing STT to lower secondary education pupils, but the experiment was not possible to conclude when schools were closed in March 2020 due to COVID-19-related restrictions. Therefore, the study's design was altered, and the data collection that was initially planned for April 2020 was postponed until November and December 2020. Even though the informants received instructions on how to use STT and practised using the technology for approximately 10 weeks, there was a gap of 8 months before we conducted follow-up interviews with teachers and stimulated recall interviews with pupils. The informants reported that they did not use STT regularly during this period. Thus, the teachers and pupils had not been using STT regularly during the months between April and November, which may have influenced their experiences and perceptions of using the technology. They

also reported frustration and awkwardness, which could have been reduced had they been given the opportunity to become familiar with the technology and practise using STT over time.

A methodological limitation of this study concerns the inclusion criteria for participants in Article 3. Mainly, it was difficult to find reliable measures of writing difficulties in lower secondary education. Therefore, we decided to combine three measures, (1) the national reading test, (2) a standardised spelling test and (3) teacher nominations, to increase the probability of identifying the pupils with writing difficulties. Another limitation regarding Article 3 was discovered during the data collection and analysis of the stimulated recall interviews. During the interviews, the pupils with writing difficulties appeared to be more willing and able to describe the content of the writing assignment rather than their experience of writing with STT. In hindsight, we observed that providing the pupils with open-ended 'what'-, 'how'- and 'why' questions, as recommended in the methodological literature (Vesterinen et al., 2010), was not sufficient for the adolescents with writing difficulties. The stimulated recall approach presupposes that pupils have a meta-language, a vocabulary that enables them to reflect over and discuss a communicative situation (Pelger & Sigrell, 2015). Even though the pupils knew that we were interested in their writing experiences and not in the content of their texts per se, they appeared to struggle with this distinction and often described ideation and text content and, to a lesser degree, other aspects of their writing experience. Therefore, future research on STT (and other writing approaches) should consider that stimulated recall is a demanding approach for adolescents with writing difficulties and that they may need more specific instructions and guiding prompts during interviews than adults or writers without difficulties.

Exploratory designs intend to gather insights and information, rather than to provide generalisable results that are representative of broader groups (Denscombe, 2017). Thus, the findings presented in the current study are not generalisable to the population of lower secondary pupils with writing difficulties in the Norwegian educational context. This is primarily because the study employed a specific kind of open-access STT technology from Apple and Microsoft, which may have been less accurate than licenced STT software, such as Nuance® (Dragon Speak). Neither can the findings be directly generalised to other countries, as some of the analyses are specific for the use of STT in Norwegian. Similarly, research conducted in 2020 cannot be generalised to the future use of STT in educational contexts. STT is rapidly developing, and some of these findings may already be outdated. Rather, the findings should be taken as examples of phenomena that may be further explored in future national and international research on the use of STT as a writing approach.

Furthermore, future research should look into the possibility of allowing pupils to choose alternative writing technologies and explore how they experience

using STT during homework assignments or for collaborative or individual school assignments. It is also important to measure the accuracy of the different kinds of STT software and explore the availability of this technology to learners in primary, secondary or higher education. As digital software is often tested by adults, it is also important to conduct further research on the use of STT in educational contexts to explore how it is experienced by children and adolescents, male and female writers, speakers of different dialects and pupils with and without learning difficulties. Finally, further research should explore the implications and effects of using STT on both pupils' writing performance and their writing-related skills.

6. Concluding Remarks

Can speech be considered a writing tool? This study demonstrates that STT has potential as a writing approach when used in Norwegian lower secondary education. At the same time, according to the findings, STT provides both opportunities and challenges for pupils with and without writing difficulties. Although this study did not find that STT technology improved the writing-related skills of pupils with writing difficulties, it was ultimately not designed to do so. Rather, this study demonstrates that STT is an alternative approach to writing that is considered by teachers and students who have explored its use to be both feasible and beneficial under certain circumstances. For example, during the initial phases of ideation and transcription, STT provides the opportunity to produce texts using oral skills and to elaborate easily on a topic. The findings also show that STT is currently not a reliable spelling aid in Norwegian because it produces several transcription errors and requires pupils to adapt their dialects to improve accuracy.

This study's findings reveal that the potential of STT depends on the intended educational aim of introducing the technology. Four purposes of introducing STT in the secondary classroom were identified: STT as a (1) remedial or (2) instructional technology to improve pupils' transcription skills overall or STT as a (3) compensatory or (4) alternative writing technology to increase pupils' capabilities to produce written content. Further, the different aims connected to using STT vary in accordance with which groups of pupils are targeted. In particular, STT's potential appears to be partly dependent on whether it is introduced as a remedial or compensatory technology for pupils with writing difficulties or as an instructional or alternative technology, guided by the aim of increase all pupils' capabilities to produce written content. Thus, a major overriding finding of this project is that the pedagogical goal or aim and target group are important factors that impact STT's potential as an approach to writing in lower secondary education. This is an important factor in the context of creating inclusive classrooms because teachers must be able to adapt the learning environment to a diverse group of learners and consider their distinct academic and social needs.

The use of technology in education (Lai & Bower, 2019), specifically the use of STT technology during writing activities, has been described as difficult to measure and evaluate in educational research (Svensson et al., 2021). Both technology and writing are complex entities. Thus, researchers struggle to find valid and reliable measures to study the effects of introducing digital technologies in educational contexts. With its explorative design, this thesis lends itself to describing phenomena rather than measuring effects. Yet, in a little-explored area of writing research, descriptions and indications on the use of STT in educational contexts provide a valuable basis for future research. Teachers' opinions of what writing should be, or whether technology has a place in the educational context, will

influence the future accessibility of STT technology at the lower secondary education level. Indeed, educators have a great responsibility when deciding whether or not or when to introduce STT to all pupils.

For pupils with writing difficulties, the opportunity to write by speech may increase their capabilities, whereas for the majority of pupils, it is more likely to be an alternative writing approach. However, research regarding the goal of introducing STT technology is lacking. Thus, future studies should explore how and under which circumstances STT may increase pupils' writing skills or capabilities. According to this study's findings, teachers recommend that STT should be introduced prior to lower secondary education so that its potential as a technology can be fully realised. Future classroom decisions on the implementation of different writing approaches and modalities are likely to include dilemmas concerning which approaches pupils should be allowed to use.

Arguments in favour of reducing access to digital technologies in education occur as a reaction to the rapid digital shift that has been taking place in education in recent decades (Mueller & Oppenheimer, 2014; Ravizza et al., 2017; Selwyn, 2014). However, educational professionals must also consider pupils who struggle when limited to traditional writing approaches. This study's findings indicate that STT can be used to increase pupils' capabilities in an inclusive learning environment that provides them with access to alternative writing approaches. Nonetheless, to provide these opportunities, STT must be considered a functional writing approach by the educational writing community consisting of pupils, teachers, parents, school leaders and policymakers.

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Appendices

Appendix 1. Article 1

A Scoping Review on the use of Speech-to-Text Technology for Adolescents with Learning Difficulties in Secondary Education

Abstract

Purpose: To identify and describe the aims, methodological approaches, and major findings of studies on the use of STT among secondary pupils (age 12-18) with learning difficulties published from January 2000 to April 2022.

Materials and Method: This scoping review includes empirical studies published in peer-reviewed journals and grey literature between January 2000 and April 2022. Searches were conducted in April 2022 in three databases: ERIC, PsycINFO and Scopus. In addition, related reviews were manually screened for relevant papers.

Results: Eight peer-reviewed studies and five publications of grey literature were found to meet the inclusion criteria; two studies employed experimental designs, four employed quasi-experimental designs and seven employed explorative designs. Six studies described STT as an assistive technology (a compensatory aid for poor writing performance); two assessed STT as an instructional technology to determine whether it improves overall writing and related skills (e.g., reading). Results suggest that STT may increase pupils' abilities to produce texts with fewer errors, provide help with spelling and improve reading comprehension and word recognition. To date, there is a paucity of high-quality research on the use of STT among adolescents with LD.

Conclusion: The scoping review shows that very little research has been conducted on the use of STT for adolescents with learning difficulties in secondary education. Findings from the studies identified five areas of interest: writing related skills, text assessment, writing processes, accuracy of the technology, and participants' experiences. Findings indicate that writing performance among students with learning difficulties improves when using STT. Parents, teachers, and pupils report positive experiences with the technology, particularly for students with severe reading and writing difficulties.

Keywords: speech-to-text, speech recognition, special education, assistive technology,

instructional technology, writing difficulties

Introduction

Writing is a complex activity, dependent on cognitive prerequisites, such as phonological decoding [1], efficient working memory [2, 3] and knowledge of orthography, morphology and syntax [4]. Writing is also influenced by self-regulation, creativity, and self-efficacy beliefs [5, 6]. Most theoretical models of writing do not consider the use of assistive technology and its impact on the writing process [7]. Instead, they tend to focus on different cognitive aspects of the writing process, including the influence of working memory, knowledge transformation and the writer's motivation and self-regulation [e.g., 8, 9, 10]. One exception is Hayes and Berninger's [11] descriptive framework of the cognitive processes involved in writing wherein transcription technology is presented as an influential element in the physical task environment. Taking this into account, pupils who display low proficiency in writing, due to poor instruction, learning disabilities, language disorders or developmental disorders [12], may benefit from the use of speech-to-text technology (STT). Notably, this may be the case for pupils with dyslexia, who due neurological deficits in the phonological component of language, experience difficulties with accurate and fluent word recognition, and poor spelling and decoding [13].

Writing Difficulties

Based on a corpus of 41 studies, including writers in primary, secondary and higher education, Newcomer and Barenbaum [14] found that struggling writers compose texts with more mechanical errors (spelling, punctuation and capitalisation), more syntax errors (subject/predicate agreement) and less fluency (fewer words, fewer sentences and less variety of words). Compared to their typically developing peers, pupils with learning disabilities did not exhibit an increase in fluency as they grew older. The studies included in their review revealed that struggling writers demonstrate less knowledge of the writing process, such as the importance of planning. These findings demonstrate that writing difficulties can be extensive and persistent [14]. Ewoldt [15] argues that, due to deficits in

language and working memory that negatively impact the ability to produce quality writing, pupils with learning disabilities tend to focus on lower-level elements of writing, leading them to compose poorly organised paragraphs comprised of strings of linear ideas. According to Ewolt [15], technology can provide academic support for these pupils as it increases opportunities to focus on organisation, argumentation and how the text communicates to the reader.

Speech-to-text Technology

Speech-to-text technology (STT) generates digital text from spoken language. One of the first speech recognition systems was built by scientists at AT&T Bell Laboratories in 1952 [16]. In the field of special education, studies on STT as an assistive technology for writing composition emerged in the late 1980s and 1990s [17,18,19]. For example, several versions of speech-to-text programs released by Dragon Systems have enabled users to produce text by speaking into a computer microphone. Other kinds of software have also been used, such as Keystone Speech master [20], Speech Texter [21], VoiceType [22] and integrated software in Apple's iPad [23]. Speech recognition technology has improved rapidly, ranging from systems that needed to be adapted for individual users to more advanced programming that builds on deep learning algorithms, providing accuracy of 90–95% in prevalent languages [24]. Technological advancement also reflects a move from 'discrete recognition', which required users to include a pause between words when dictating, to systems that accept continuous speech [25], and newer technologies that provide suggestions or corrections based on contextual cues, such as previous words in the sentence.

When pupils transition from primary to secondary education, demands on their writing performance increase. Pupils in primary education are expected to have mastered

the basics of grammar, orthography, and punctuation and to produce longer texts in which they focus on content, communication, and structure. Consequently, teachers may introduce assistive technologies to support students with writing difficulties. However, adoption of new approaches can be challenging for older students who have spent years developing their writing skills and habits when writing by hand or typing. Thus, research on STT requires consideration of students' and teachers' willingness to adopt STT in secondary education (age 12 – 18) and the ease with which it can be applied in this context [26]. In addition, there is a need for research that considers which students are most likely to benefit from STT, under what circumstances, and how any potential benefits may occur.

Assistive and Instructional Technology for Writing
Peterson-Karlan, Hourcade, and Parette [27] define assistive technology as having a compensatory function to support pupils who struggle to write and to provide scaffolding for basic writing skills. This technology is not intended to replace writing-as-process instruction or become the student's only tool for producing texts. It is considered a support in certain areas of the writing process, especially in drafting, editing, and revising [27]. Analogous to the concepts of assistive and instructional technology are Edyburn's [28] descriptions of compensation and remediation. In these terms, compensation (assistive technology) refers to efforts to compensate for a lack of writing skills and enhance the pupil's ability to plan, compose and revise text. In contrast, remediation or instructional technology aims to improve skills by enabling pupils with LD to produce more text and increase exposure to writing activities [28]. Thus, it may not be the technology itself that differs between assistive and instructional technology, but the aim or effect of implementing the approach. For example, if researchers aim to study improvement on learning in general, they consider STT an instructive technology, while if they research the implications on a specific task (for example text quality, text length or composing time),

STT is more likely to be considered an assistive technology. The theoretical, empirical and practical distinctions between writing technology as an assistive or instructional technology have been largely unexplored.

MacArthur's [29] review of assistive technology for struggling writers in primary and secondary education notes that although evidence suggests that STT can be beneficial for some students, little is known about who can benefit from STT and in what contexts. In their broad review of STT in education, Shadiev et al. [30] summarised its benefits for students with disabilities, online students, non-native speakers and in collaborative learning activities and traditional classroom environments. Pennington et al. [31] presents a review on how STT supports writing in primary and higher education, and Arcon et al. [32] conducted a within-subjects experimental design study on how STT can be used for second language learning in elementary education. Yet, little is known about the use of STT in secondary education or its impact on specific tasks for learners with writing difficulties, and even less is known about its general impact on learning. As we have not identified previously published reviews on struggling writers' use of STT in secondary education, it is important to explore this research gap. This is especially true with respect to assistive technology, including STT, as it is widely recommended in the IEPs of students in secondary education [27,33,34], and as an educational practice for teachers and teacher candidates in theoretical frameworks [35,36], policy documents [37,38] and instructional materials [39,40].

Purpose of the Review

Several systematic reviews and meta-analyses have been conducted on studies of assistive technology for pupils with learning impairments [41,42,43,44,45,46], and reviews on assistive technology to support learners who struggle with reading and writing [47]. However, no previous literature reviews have focused on the use of STT among struggling

writers in secondary education (age 12 – 18). As there is little existing research on this topic, we decided to conduct a scoping review. The aim of a scoping review is to systematically map evidence on a topic and identify the main concepts, theories, sources, and knowledge gaps [48]. The purpose of this study is therefore to identify and describe the aims, methodological approaches, and major findings of studies on the use of STT among secondary pupils with learning difficulties published from January 2000 to April 2022. Based on this review, we describe research gaps in current research and make recommendations for improvement.

Methods

Literature Search

This review focuses on grey literature and peer-reviewed empirical studies published in English between January 2000 and April 2022. We chose January 2000 as a starting point, as the technological advancement of continuous speech recognition was first implemented at that time [49]. Continuous speech recognition created a shift in the usability and accuracy rate of speech technology. Studies published prior to January 2000 were excluded, as they only report findings on the use of discrete word recognition software.

Searches for peer-reviewed articles were conducted in three databases in April 2022: ERIC, PsycINFO and Scopus. Review studies conducted by Pennington et al. [31], Perelmutter et al. [46] and Peterson Karlan et al. [27] were screened for relevant papers. The following search string was used for all three databases (writing OR student* OR school OR education* OR special AND education* OR writing AND disorder* OR dyslexia OR learning AND disabilit*) AND (speech AND technolog* OR speech AND to AND text OR speech-to-text OR speech AND recognition OR stt OR dictation). Search terms were selected according to the Participants, Interventions, Comparisons and Outcomes (PICO) framework [50]. Only terms describing participants (pupils, education,

dyslexia, disabilities) and interventions (STT, dictation, assistive technology) were included in the search string to avoid limiting the search to specific comparison groups (disabled versus non-disabled) or outcome measures (motivation, skills, experiences).

Searches for grey literature were conducted using title and keywords searches in Google, Google Scholar, the NDLTD (Networked Digital Library of Theses and Dissertations) and ProQuest Dissertations & Theses Global. Keyword searches included combinations of the following terms, "speech recognition", "speech-to-text", "STT", "dictation", "writing", "learning disabilities", "dyslexia", "writing disorder", "writing difficulties", "special education" and "secondary education". We also conducted citations searches and manual searches on all included articles and related review articles [such as 27,46]. Given the broad range of possible sources, the search process for grey literature has a greater number of limitations and is likely less exhaustive than with peer-reviewed literature.

Selection Criteria

Articles were included or excluded according to a set of criteria regarding (1) target population, (2) research aim and (3) whether they were original research studies. See Table 1 for an overview of inclusion and exclusion criteria.

[Insert Table 1 about here]

1. Target Population

Studies of learners with difficulties that directly relate to developing writing skills, such as dyslexia, dysgraphia or specific language impairment, were included. Articles describing speech recognition users from different age groups were included if the participants were secondary education pupils (ages 12 to 18). Studies were excluded if they only targeted 'typical learners': pupils with average or above average writing proficiency. Studies of learners with intellectual impairments or physical disabilities, were also excluded; this diverse group of students may or may not have similarities with learners who primarily

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struggle with written language. Studies including only children in early childhood education or primary school, as well as studies on adults, were excluded. In this review, we have chosen to use the term, 'learning difficulties' (LD) instead of 'learning disability', as it was necessary to include studies on struggling writers who may not have a diagnosed disability, given the paucity of research within this field.

2. Research Aim

Speech technology is often regarded as speech recognition (speech-to-text) and speech synthesis (text-to-speech). The aim of this scoping review is to identify research aims, areas of interest and methodological approaches of studies on speech-to-text technology for pupils with learning disabilities in secondary education. Thus, articles that include the use of either speech recognition alone or speech recognition combined with other kinds of assistive technologies (such as speech synthesis or digital voice feedback) are included. Studies on speech recognition for second language instruction (e.g., Arcon et al. [32]) and speech- and language therapy (e.g., Kitzing et al. [51]) were excluded.

3. Original studies

Theoretical papers on how to implement speech technology and position papers on the use of speech recognition in the classroom were excluded if they did not report empirical data. Meta-analyses, systematic reviews, and literature reviews on assistive technology were included in the first screening, and relevant articles found in the reviews were included in the second screening. Larger studies on the general use of assistive technology, listing speech recognition as one of several technologies, were excluded if they did not report a specific sample using STT (e.g., Flanagan et al. [52]).

Screening and Eligibility

The first author used Rayyan (www.rayyan.ai), a digital platform for document reviews and data extraction, for the initial screening of titles and abstracts of 2380 articles. Thereafter,

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2227 articles were excluded as they were off topic or did not meet the inclusion criteria. In a second screening for peer-reviewed articles, 79 articles that could be considered eligible based on title and abstract were read individually by the first and second author. Both authors concluded that five articles [25,53,54,55,56] met the inclusion criteria. Three additional articles [23,57,58] were identified through manual searches. The three articles were read individually by both authors and found to fulfil the inclusion criteria, resulting in a total of eight articles. Inter-coder reliability of the eight articles was 100%. The PRISMA-ScR (Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews) Checklist [59] was used to guide the reporting of findings. An overview of the screening and selection process is presented in Figure 1. Grey literature was searched and screened individually by the first author. Only literature that reported on and met the inclusion criteria, such as empirical findings and participants within the age range, were included. Five publications of grey literature met the inclusion criteria: three reports [60,61,62,], one dissertation [63] and a preprint article [64].

[Insert Figure 1 about here]

Analysis

First, the eight peer-reviewed articles meeting the inclusion criteria were coded according to study design, research aims, sampling methods, sample size and age, country, proportion of learners with and without LD, duration of the study, characteristics of the intervention and STT software. Studies were categorized based on their stated purpose and the methods of analysis reported by the author(s), as well as the extent to which they contained components of experimental designs. The four essential components of a true experimental design include (a) random selection, (b) random assignment, (c) the presence of an intervention (i.e., manipulation of the independent variable), and (d) the use of a comparison or control group [65]. As random selection is rare in instructional research

[66,p.323], quasi-experimental designs were in this study required to include at least random assignment, a comparison group and an intervention. Qualitative studies were determined based on the absence of quantitative measures and the clearly distinguishable purpose of developing meaning rather than testing for causal relationships [67]. An overview of study designs, sample sizes and methodological approaches is presented in Table 2 for peer-reviewed articles and Table 3 for grey literature, along with a summary of the main findings from the studies.

[Insert Table 2 about here]

[Insert Table 3 about here]

Secondly, we identified the primary variables investigated across the studies and derived the following areas of interest from this analysis: *writing related skills*, *text assessment*, *writing processes, accuracy of the technology, and participants' experiences*. The areas of interests are intended to capture a combination of outcome measures from experimental studies as well as explorative variables that reflect the stated aim of the studies and that were most prevalent in the studies' reported findings.

[Insert Table 4 about here]

Results

Given that the quality of peer-reviewed articles has been previously established to separate grey literature from scientific publications, findings from the articles and grey literature are presented separately.

Aims and Approaches

<u>Peer-reviewed studies</u>

Four peer-reviewed studies used quantitative approaches, two studies [53,57] filled the criteria for experimental designs and three [25,54,56] were defined as quasi-experimental

approaches, as they did not conduct randomised sampling or had post-test only designs.

Two studies [23,55] employed explorative designs and mixed methods approaches, while

one study [58] had an explorative and qualitative approach. Information on the design,

sample characteristics and software used in the included studies is presented in Table 1.

Jeffs et al., [58] Nordström et al. [23], and Ok et al. [55] conducted explorative

studies based on surveys or interviews after the participants had used STT over a brief

period of time. Jeffs et al. [58] sought to study characteristics, interactions, and the attitudes

of parents and pupils related to their use of assistive technology. The researchers observed

eight children with LD as they used a variety of assistive technologies, including STT.

Afterwards, they interviewed the children and their parents to access their reflections on

assistive technology's impact on literacy learning. Nordström et al. [23] examined teachers'

views on the capacity of assistive technology to give learners with documented reading and

writing difficulties the opportunity to assimilate ('read') and communicate ('write') text.

Data comprised special education teachers' (n = 54) perceptions of pupils' (n = 59)

experiences using the technology in grades 4 and 8, and upper secondary school. Ok et al.

[55] examined usage patterns and perceptions of speech recognition among 95 pupils with

learning disabilities (grades 4–8), while teachers and pupils participated in interviews.

Noakes et al. [56] utilized an alternating treatment, single-case design including

three pupils (ages 9, 14 and 15) with written expression difficulties due to traumatic brain

injuries. The study's aim was to measure STTs effect on text length, grammar, and spelling.

Noakes et al. [56] compared the pupils' texts composed under two conditions, writing by

hand and while using STT. Four studies [25,53,54,57] employed between-group designs.

Quinlan's [54] aim was to investigate STT's effect on the writing processes of students

described as "more fluent" and "less fluent" writers (n = 41, ages 11–14). Aiming to

measure the effect on the writing process, Quinlan examined the outcome measures holistic

text quality, text length, number of errors, planning time, composing time, revising time, accuracy of the technology and amount of planning words. MacArthur and Cavalier [25] examined the feasibility and validity of using speech recognition as a test accommodation. They compared STT to writing by hand and with a scribe among LD students and students without LD (NLD) in upper secondary school (n = 31, mean ages: LD = 14.7, NLD = 15.1).

Svensson et al. [57] explored the effects of several kinds of assistive technologies, including STT, on reading and writing related skills. The study included 149 pupils with LD in grades 4 (age 9), 8 (age 13) and upper secondary (age 16-19). An intervention group received assistive technology training while a comparison group received teaching as usual. Pre- and posttests included standardised assessments of reading and writing related skills. A survey was presented post intervention to pupils in the intervention group and their parents to assess perceived motivation. Higgins and Raskind [53] compared the effects of interventions using two types of speech recognition systems, continuous and discrete speech, and aimed to measure the remedial effects of STT on writing related skills for pupils with identified LD (n = 52, ages 9–18). Thus, of the eight identified studies, only two, Higgins and Raskind [53] and Svensson et al. [57], assessed changes in writing related skills after exposure to an intervention using a pretest-posttest design and a comparison group.

Grey literature

Included grey literature comprise three reports [60,61,62], one dissertation [63] and a preprint article [64]. The dissertation by Mader (63) employed a quasi-experimental alternating treatments single-case design. Participants (n=3, age 11, 13 and 14) composed narratives using paper and pencil and STT. The researcher collected both qualitative (semi-structured interviews) and quantitative data (self-reporting surveys, document analysis and

psychometric tests) aiming to investigate the use of STT with adolescents with learning disabilities. More specifically, Mader's [63] research questions examined (1) STT's effect on the quality of student compositions, (2) the affective dimension of writing and (3) the accuracy of the technology.

The remaining four identified grey literature publications employed explorative research designs. Three of them are reports [60,61,62] by the governmentally funded research and development centre CALL (Communication Access Literacy and Learning) Scotland. Nisbet and Wilson [60] and Nisbet et al. [61] report from *the Introducing Speech Recognition in Schools* project that provided training and speech recognition software to forty schools. Staff from twenty-three schools (57,5%) returned evaluation forms with open-ended and closed questions reporting on 32 pupils (age 13-16) use of STT. The aim of the project was to investigate best practice in schools where STT was being used successfully, as well as to develop and evaluate training material to help other schools implement STT.

Lawson and Nisbet [62] report on the *Talking in Exams* project. The project aimed to investigate the use of STT for pupils with disabilities or additional support needs, during formal assessments. Twenty-eight schools were provided with STT software, and 70 pupils (age 10-17) participated in the trials. Teachers were asked to complete a pupil record for each learner describing underlying reasons for need of support, indications of the student's reading, writing, verbal and ICT skills, motivation to use STT, outcome of the trial and key advantages and disadvantages. Feedback was received from 12 schools (60%) regarding 39 (56%) of the 70 pupils.

Levine et al. [64] registered their article as a preprint (not yet peer-reviewed as of October 2022) on SSRN (Social Science Research Network). The aim of their study was to explore voluntary use of STT among general education English Language Arts (ELA)

students. The study included 120 pupils (age 14-17) of which 73 (60%) attended ELA support classes. The researchers gathered quantitative data (a mid-year survey and end-of-year survey) and qualitative data (interviews and observational notes) to explore who used STT, the kinds of composition tasks pupils chose to do with STT, and pupils' and teachers' perceptions of STT. The study also compared STT compositions written with STT with similar compositions written without STT to explore potential differences in writing.

Main Findings from Peer-Reviewed Studies

Analysis of the main findings from the 8 peer-reviewed studies was organized around the five identified areas of interest described above: writing related skills, text assessment, writing processes, accuracy of the technology, and participants' experiences (see Table 4 for an overview).

Writing related skills

Two studies [53,57] addressed reading and writing skills as outcome variables. Higgins and Raskind's [53] labelled their outcome variables as reading and writing related skills (word recognition, spelling and reading comprehension) and reading related cognitive processing measures (phonological deletion, orthographic choice, semantic choice, metacognitive ability and working memory). Higgins and Raskind [53] included three groups of students with instructional programs using different technologies: continuous speech recognition, discrete speech recognition or keyboard only (contrast group). The discrete condition required students to dictate word-by-word with a pause between each word, while continuous speech recognition allowed the users to speak in full sentences. In comparison to the contrast group, both the discrete speech and continuous speech groups showed significant gains on reading comprehension and word recognition after 16 weeks, while significant gains in spelling were found only for the discrete speech condition. No significant between-group differences were found for any of the cognitive processing

measures, with one exception: students provided with the discrete speech condition had significantly higher scores on the phonological deletion measure than the contrast group. There were no significant differences between the two STT conditions on any of the eight outcome measures [53].

Svensson et al. [57] employed test batteries measuring reading and writing related skills such as word recognition, reading and listening comprehension, orthographic choice, short-term memory, and fluency. The tests were conducted pre- and postintervention, and after 1 year. The intervention had a duration of 8 weeks and procedures included several kinds of assistive technologies aimed at assimilation (reading) and communication (writing) of text. Results showed that the intervention and comparison groups did not differ on any of the tests, after the intervention, or at the 1 year follow up. The study concluded that pupils receiving assistive technology as reading and writing instruction maintained the same pace of developing reading and writing related skills as did the pupils who received treatment as usual. The test battery employed in the study by Svensson et al. [57] mainly included skills related to reading, as they found it difficult to find tests that capture pupils' writing skills.

Text Assessment

Three studies [25,54,56] compared pupil performance using STT to their performance using other modalities. MacArthur and Cavalier [25] and Quinlan [54] also considered the differential impact of student ability on writing performance by including LD students and NLD students. Quinlan [54] found that less fluent writers produced more words and had significantly fewer errors when using STT than when writing by hand. For more fluent writers, differences between texts written under the two conditions (STT and handwriting) were not significant. A 5-point scale measuring story development and sentence fluency (t-

units) was used to assess text quality. No significant differences were found between the quality of texts under the two conditions for either group of students.

MacArthur and Cavalier [25] compared the writing of LD and NLD students under three conditions: handwriting, dictation to a scribe and STT. They used a rubric to measure holistic text quality on a 7-point scale, which included assessment of ideas/content, organisation, word choice, sentence fluency and writing conventions. For students in the LD group, the highest quality texts were produced when dictating to a scribe, while texts written with STT received significantly higher quality ratings than texts written by hand. No differences in text quality were found for the NLD group when using all three modalities. The results showed significantly fewer errors in texts written by LD pupils using STT in comparison to handwritten texts. Moreover, MacArthur and Cavalier [25] found no differences between modalities with respect to the number of errors produced by NLD pupils. Furthermore, there were no significant differences between the three modalities on text length or vocabulary use, regardless of the ability group.

Noakes et al. [56] aimed to measure STT's effect on writing for three pupils with traumatic brain injuries. The study employed three outcome variables, (1) total words written, (2) words spelled correctly and (3) correct writing sequences. All outcome variables significantly increased when the pupils used STT and were higher than the handwriting control condition.

Writing Processes

MacArthur and Cavalier [25] and Quinlan [54] considered elements of the writing process, such as the amount of time students spent composing, revising, and planning with different modalities. Quinlan [46] found that average composing time was longer for STT than for handwriting across all participants. MacArthur and Cavalier [25] found no significant

differences between handwriting and STT on composing time for either group of students. However, both NLD and LD students wrote significantly faster using a scribe than with handwriting or STT. MacArthur and Cavalier [25] found no differences between conditions on planning time, yet both groups of pupils spent significantly less time revising texts when writing by hand than when using STT or a scribe.

Accuracy of the Technology

Two peer-reviewed studies [25,53] report on pupil dropout due to low levels of accuracy; inaccuracy of the technology was listed as the main weakness in several studies. Four of the 38 students dropped out of Higgins and Raskind's [53] continuous speech condition due to low accuracy rates; two did not complete the discrete condition because they found correction of speech recognition errors frustrating and typing more efficient. MacArthur and Cavalier [25,p.47] describe one of 21 LD students who did not complete their study because she found it 'frustrating'.

Both studies [25,53] employed a probe task in which the participants read passages aloud while using speech recognition, without correcting recognition errors. Mean accuracy in Quinlan's [54] study was approximately 90%, where accuracy was significantly related to age, but not to writing skill. Higgins and Raskind [53] suggest that the higher pitch of younger pupils' voices may hinder the accuracy of STT. In MacArthur and Cavalier's [25] study, 13 students showed a mean accuracy rate of 87%. Although not measured in these studies, it is assumed that the accuracy rates for a probe task using handwriting to reproduce the same passages would be close to 100% for most students. Quinlan [54] notes that some children experienced few recognition errors while others encountered several and spent considerable time and effort correcting them. Variability in functionality across individuals was highlighted across the studies included in this review.

Experiences

Five peer-reviewed studies [23,25,55,57,58] report on parents', teachers', or pupils' self-reported experiences with STT. MacArthur and Cavalier [25] collected data on pupils' opinions of using STT, including its strengths and weaknesses, and which modality they preferred; 62% expressed positive views of STT, 66% reported that they would continue using STT for future assignments and 96% said they would recommend STT to a friend. When asked to compare writing with STT to dictation to a scribe and writing by hand, 65% of the pupils in MacArthur and Cavalier's [25] study preferred using STT. Moreover, 82% agreed that STT helped them write better texts. The pupils listed, "speed, not having to write, help with spelling, [that it was] fun or 'cool', and helping to get thoughts down" as benefits of using STT [25,p.53]. All the pupils who listed 'help with spelling' had a documented LD. The most frequent criticisms reported were mistakes in recognition, correction errors, and difficulties training the speech recognition system [25].

In Ok et al. [55], 50% of 7–8th grade pupils expressed that they liked using STT and 66% believed it improved their writing, yet some students reported that using STT felt like cheating and that speaking out loud in the classroom was embarrassing and distracting. In contrast, 74% of teachers in 8th grade and upper secondary reported that they believed STT improved students' ability to write [55]. The teachers described challenges such as difficulty finding a quiet place, distractions, improper use, lag time due to internet connection issues, anxiety about speaking out loud and limited teacher competency [55].

Nordström et al. [23] found that 81% of special educators believed that the intervention improved students' ability to compose texts. However, only 42% assessed the technology as having improved 'traditional' reading and writing skills, and only 38% perceived writing with STT as having a positive effect on motivation. Nordström et al. [23]

and Ok et al. [55] found that younger pupils were more likely to continue using STT after the intervention than older pupils.

Between 42% and 55% of pupils in Svensson et al.'s [57] study perceived that the STT-intervention positively affected motivation and independence. Analyses showed that this finding was especially valid for pupils with the most severe reading and writing difficulties. Svensson et al. [57] conducted the only longitudinal study identified, measuring pupils' attitudes one year after the intervention, finding that 65% reported that they still used the assistive technology apps after 1 year. Jeffs et al. [58] interviewed and observed parent-child dyads using assistive technology during reading and writing activities. The main findings regard the pupils and parents' changing attitudes towards literacy. The pupils with learning disabilities had a history of avoiding reading and writing activities, and their parents described their struggle to assist them in completing literacy tasks. STT was reported as an easy approach that all the children enjoyed using. However, it was also emphasized that it was difficult to train the speech recognition system.

Moreover, parents reported that the technology provided a sense of encouragement. Yet, introducing STT required that the pupil acquire different software skills, in addition to new writing strategies of planning texts and organizing their thoughts. According to Jeffs et al. [58], one of the main benefits was that the pupils who had previously been negative towards reading and writing activities experienced pride and ownership while reading and writing with assistive technology.

Main Findings from Grey Literature

The main findings from the grey literature vary greatly in quality, form, and genre. The three publications by Nisbet and Wilson [60], Nisbet et al. [61] and Lawson and Nisbet [62] are all presented as reports, but most of the content comprises tutorials describing how

practitioners can introduce secondary pupils to STT for regular writing activities (a and b) or during formal writing assessment (c). In addition to the sections on how to dictate with STT, the reports provide results from evaluations conducted with the staff and students who took part in a project entitled CALL *Introducing Speech Recognition in Schools*. Findings presented in the reports show that the success of introducing speech recognition in schools depends as much on school and staff resources, as on the skills of the individual student. Further Nisbet and Wilson [60] found that 72% of students who were introduced to STT during the CALL-project intended to continue using the technology, while 3% were unsure and 25% reported that they did not intend to continue using STT.

Nisbet et al. [61] describe large variations in the training sessions depending on the reading and ICT skills of students. The pupils' reading skills were influential because the pupils had to read a text to train the STT technology. Nisbet et al. [61] further noted that the pupils' motivation to use STT tended to be rated "good" or "excellent", and there was little difference between successful and unsuccessful pupils in relation to motivation. Learning to use STT was described as hard work and at times frustrating, therefore pupils and students had to be prepared to put in a lot of effort to get useful results [61].

In the last report by Lawson and Nisbet [62], teachers were asked to rate how likely it was that their pupils could use STT in an exam setting. Fifty-four percent indicated "maybe", 28 % said "yes", 17% said "no" and 5 % did not respond. Teachers reported advantages such as the opportunity to overcome concerns about spelling, higher independence and self-esteem, and that the pupils wrote faster with STT compared to writing by hand or typing. Reported disadvantages include that STT did not work as well for pupils with indistinct speech and that some pupils did not enjoy being "put on the spot," as they experienced pressure to produce text.

The dissertation by Mader [63] aimed to study how STT influences the quality of written composition and affect attitudes and self-perceptions towards writing. Findings suggest that STT can assist students with learning disabilities to produce better written products and it positively affects attitudes and self-perceptions towards writing. In the pre-printed article, Levine et al. [64] explored use of STT among general education English Language Arts students in two high schools. Their findings showed that STT could serve as an accessible alternative mode of composition for some high school students and were especially useful for students with writing related learning disabilities. Additionally, they saw that students with learning disabilities were more likely to use STT than other groups, and that the students preferred to use STT for drafts as opposed to revisions. A final finding from Levine et al. [64] was that older students were less likely than younger students to use STT in the classroom.

Discussion

This scoping review presents a small, yet important, collection of studies on how pupils with LD use STT in secondary education. Research on STT is clearly still in its infancy. Only eight peer-reviewed studies and five publications of grey literature met the inclusion criteria. Due to widely varying research aims, designs, and quality of studies, results are difficult to synthesise. The current review finds that existing research on STT for pupils with LD in secondary education has primarily focused on STT as an assistive technology to enable pupils to produce texts with fewer errors and more content, rather than an instructional tool aiming to improve reading and writing related skills across modalities.

STT as an Instructional Technology

The two studies [53,57] that assessed STT in relation to writing related skills, found significant gains on reading comprehension, word recognition and in spelling for the group using discrete speech recognition. It appears that these distinct STT approaches may have

slightly unique advantages. In general, these studies suggest that STT can produce remedial effects in selected literacy skills. Lange, Mulhern, and Wylie [68] describe remedial effects as intentions to improve basic skills directly, while the compensatory effect aims to enable pupils to complete tasks on their own when using the technology. Edyburn [28] argues for a dynamic approach to determining when assistive technology can be considered either remediation or compensation. The degree of compensation must be adjusted over time and considered in relation to the learner's ability to develop writing skills and their need for support.

Higgins and Raskind [53] focus on the remedial effect of STT (as instructional technology) and did not measure its compensatory effectiveness (as assistive technology). They report that STT could potentially be used to improve reading comprehension, word recognition, and spelling among students with LD. However, we did not find any studies that considered the remedial effect of STT with respect to writing related skills for LD and NLD pupils. It is noteworthy that spelling is the only specific writing measure included in the studies of STT as an IT [53,57]. The other measures are termed *writing related* skills, such as reading proficiency and cognitive prerequisites for literacy (e.g., metacognitive ability, short-term memory). Thus, there is a significant need for more research on STT as an instructional technology with LD students, and especially on its effect on writing skills.

STT as an Assistive Technology

It is promising that MacArthur and Cavalier [25] and Quinlan [54] suggest that STT can be an effective assistive technology for improving writing performance among LD pupils in comparison to other modalities. However, the benefit to NLD pupils in secondary education was found to be minimal or non-existent. This is similar to the findings of Haug and Klein [69] who examined the use of STT compared to handwriting to teach argumentative writing among 45 NLD pupils in 5th grade. No significant differences were found between the two groups with respect to either the quality of texts or pupils'

perceptions of required effort. Yet, all students demonstrated gains in the variety and quality of arguments under both conditions. MacArthur and Cavalier [25] and Quinlan [54] describe improved writing performance and higher holistic text quality for pupils with LD; they report that less fluent writers displayed fewer surface errors using STT. This is in line with research in elementary school on the use of STT as an assistive technology for English language instruction [32] and as an approach to promote idea generation [58]. That younger pupils and pupils with LD have similar benefits of STT as an assistive technology, may be due to similarities among the two groups with respect to limited working memory and transcription skills that are not yet fully developed [32].

Nordström et al. [23] and Ok et al. [55] did not directly measure STT's influence on writing processes. However, these two explorative studies provide insights about how STT might be effectively implemented in classrooms as an assistive technology. Both studies [23,55] underline the importance of adequate support. For example, Ok et al. [55] suggest that environmental support, device support, and instructional support facilitate integration of STT in everyday use. Cited environmental supports include the need for a quiet place, a comfortable environment for speaking out loud and a stable internet connection. Device support entails appropriate hardware (e.g., headphones with microphones) and software with high speech recognition accuracy. Instructional support includes the opportunity to practice verbal skills, learning to edit and providing scaffolding for writing and editing, such as checklists and prompts.

Acceptability and usability

Across the five peer-reviewed studies that examined teachers', parents', and pupils' experiences with STT [23,25,55,57,58], acceptability and perceived usability of the technology was generally high. Findings suggest that the majority of students were motivated to use STT [25,57,58] and that many pupils with LD continued using it after interventions had ended. It is further encouraging that pupils [25,55], teachers [23,55], and

special educators [23] perceived STT to have a positive impact on the quality of student writing, in particular with respect to spelling.

However, not all participants in the reviewed studies preferred STT to traditional approaches. Students with more severe reading and writing difficulties [25,57] and younger students were more positive than were older students and students without difficulties [23, 55]. Ok et al. [55] suggest that younger pupils may experience less frustration when adopting STT, as they more easily assimilate it into the writing process because they have not yet established other strategies to address challenges they encounter in spelling, grammar, and text production. Differences among students with respect to the perceived effectiveness and usefulness of STT indicate that while it can be a tool for promoting engagement in writing, it is not necessarily equally suited for all learners. In addition, there is little evidence from the current review to indicate that student motivation derived from STT use is transferred to writing in other modalities [23].

The challenges that study participants reported can be broadly grouped into three categories: technical, contextual, and emotional barriers. Technical challenges comprise elements that are inherent in the technology itself, such as word recognition errors, the time required to train or set up the system, and the effort needed to revise and correct mistakes that pupils do not normally make when writing by hand or on a keyboard [25,58]. Contextual factors include concerns such as teachers', pupils', and parents' lack of competency in using the tool, students' inappropriate use of the technology, and questions about when and where to use it without distracting other pupils [55,58]. Emotional difficulties include students feeling embarrassed or as though they are "cheating" when they use STT, and feelings of anxiety or frustration with the technology [25,53,55,57]. While the overall evidence gained from the current review pertaining to the acceptability and usability of STT is encouraging, it is clear that it is not yet a tool that teachers and

pupils can implement without sufficient preparation, time, and ongoing support [23,58]. Since the invention of STT decades ago, the quality of the technology has improved substantially. Continued technological developments in STT may potentially resolve many of the challenges we see today. However, there remain a number of areas that require further exploration and where the current research base is insufficient.

Weaknesses in the Literature

The studies included in this review employ diverse methodological approaches, which infer different claims about the knowledge that can be acquired, as well as the implications of research findings. The capacity of researchers and educators to make generalizations based on the outcomes of these studies is limited both by the extent of evidence available and the reliability and validity of this evidence. Thus, it is important to also consider the quality of the studies in this review. However, assessment of study quality is a contested issue [70,71]. Davies, Nutley and Smith [72] describe a methodological hierarchy for quantitative methods where some study designs are considered to provide more robust evidence of effectiveness than others. In traditional methodological hierarchies, high-quality secondary research is preferred to single studies, randomised experiments over quasi-experiments, and experimental research is seen as superior to observation [72].

Newman and Gough [71,p.13] present three elements to consider in critical appraisal of studies: "[1] the appropriateness of the study design in the context of the review in question, [2] the quality of the execution of the study methods and [3] the study's relevance to the review question". The studies in this review have designs that are appropriate and relevant to examine the research questions that they seek to answer, yet these designs vary in quality and differ with respect to the knowledge-claims that they can make. Particularly with respect to grey literature, the assumptions regarding quality assurance inherent in the peer-review process are per definition absent. Thus, it is not surprising that these publications tend to be less robust and of lower scientific quality.

Only two studies [53,57] employed experimental designs with randomised sampling, pretests, posttests, and comparison groups. One study [56] conducted pre- and posttests and employed a single case design with alternating treatments. Two studies [25, 54] tested pupils only after the intervention and had two groups (LD pupils and NLD pupils) using different writing modalities. Three studies [23,55,58] labelled their designs as explorative, which is an approach that does not allow the researcher to draw robust conclusions about the effectiveness of using STT. Instead, the aim of these studies was to explore parents', teachers', and pupils' experiences with introducing STT to reading and writing activities in secondary education.

In summary, we find that both the quantity and the quality of research investigating the use of STT among adolescents with LD is currently insufficient to make strong recommendations for educational practice. This is in line with claims by Haug and Klein [69], and Peterson-Karlan [49] who argue that STT may not yet be considered an evidence-based writing approach as there are not enough high-quality studies. Nonetheless, based on the findings of this review, we can suggest indications as to what is needed in future research and propose tentative recommendations for practice.

Recommendations for Research and Practice

Based on this review, it is evident that the use of STT provides opportunities and challenges for writers with learning difficulties in secondary education. While only 8 peer-reviewed articles and 5 publications of grey literature were identified, the findings are generally promising. The results suggest that STT may increase a pupil's ability to produce texts with fewer errors, provide help with spelling and improve reading comprehension and word recognition. With respect to the reported experiences of pupils, teachers, and parents; it is clear that educators need to evaluate and customise how learners adapt to STT. The degree of compensation must be adjusted over time and considered in relation to the learner's ability to develop their writing skills and their specific needs for support.

Professionals must carefully evaluate the age at which struggling writers should be introduced to STT, taking into consideration that pupils appear to be more positive towards STT at an earlier age.

The distinction between using STT as primarily an assistive or instructional technology also needs to be further explored and is, to date, poorly accounted for in the literature. Evidence indicates that NLD students are not negatively impacted by using STT and may even receive specific benefits. Thus, further investigation of STT implementation among different groups of students in the same classroom is warranted. It is possible that students would be more willing to adopt STT if it were introduced as a writing approach in a full class setting including both LD and NLD students. Nonetheless, findings highlight the need for support in all phases of implementation of STT in secondary education and emphasize the importance of collaboration between school and home regarding technology and writing strategies.

Limitations

Findings should be considered in light of the limitations of the current study. This scoping review only includes studies on struggling writers in secondary education published from January 2000 to April 2022. The period could have been extended to include earlier studies on STT, as well as older and younger users, to show that both effect studies and explorative studies have been conducted on STT in primary and higher education for several decades [19,69]. However, in the last 20 years, the technology has changed dramatically, and we determined that studies using older versions of software, very different methodologies, and widely diverse student groups (with substantial variations in learning objectives) would be too expansive and limit the reliability and quality of the current review.

In addition, we chose to separate the process of writing from the process of reading. While these processes are intertwined, they are different. We sought to isolate one kind of

assistive technology from other technologies to analyse specific aspects of writing related skills rather than to describe a variety of digital writing activities in the secondary classroom. This is a further challenge in the current review, as it was difficult to isolate the effects of using STT alone, given that many of the studies used STT in combination with other approaches. Students often use spellcheck, digital mind maps, text-to-speech (speech synthesis) and other kinds of assistive technologies in addition to STT, engaging in a range of compensatory tools for writing *and* reading activities. Future reviews may benefit from including examinations of the implementation, user experiences, and effects of these and other technologies in combination, as well as their differential effects on both writing and reading outcomes.

Conclusion

With only 8 peer-reviewed studies included in this scoping review, it is evident that there is a need for more robust research on the use of STT in secondary education before a systematic review can provide further insights into its effects on writing related skills and performance for struggling writers. There is a significant need for more international research, as all the identified studies were conducted in just three countries: Sweden, the United States and Scotland. The accuracy of the technology varies between different languages; thus, accuracy is an important variable when assessing pupil's texts and experiences of using STT in education. In the current era of rapidly developing educational technology, research is needed to discover how STT influences struggling adolescent writers in educational settings as the quality of the technology improves and STT is acknowledged as another legitimate tool for writing.

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Table 1. Inclusion and exclusion criteria

Question component	Inclusion criteria	Exclusion criteria
Age	Studies including pupils aged 12-18	Studies including only pupils in kindergarten, pre-school or aged 6-11 or older than 18
Impairment	Studies including reading, writing or language impaired learners	Studies including only non-impaired learners or learners with physical or intellectual disabilities
Technology	Studies on STT or STT and other kinds of technology such as text-to-speech (TTS)	Studies not including STT, or studies were the sample using STT was not specified
Language	L1	L2
Methodological design	Quantitative. qualitative and mixed methods	Non-empirical
Year of publication	2000-2022	<2000
Intervention	Any	
Language	English	Other languages than English

Table 2. Peer-Reviewed Studies Included in the Review

Study	Country	Sample (LD[1])	Age	Approach	Design	Sampling	SR Software	Method-ology	Key findings
Higgins and Raskind (2000)	USA	52 (52)	9-18	Experimental	Pretest-posttest, Between Groups- Design	Random assignment	Dragon Dictate, Dragon Naturally Speaking v1 and IBM Voice	Quantitative	Both intervention groups showed significant improvement in word recognition and reading comprehension.
MacArthur and Cavalier (2004)	USA	31 (21)	Mean 14,7 (LD[1]) 15,1 (NLD[2])	Quasi-experimental	Posttest only, Between Group- Design	Strategic	Dragon Naturally Speaking v4	Quantitative	Dictation helped students with LD produce better quality essays. No differences in text quality found for students without LD.
Quinlan (2004)	USA	41 (21)	11-14	Quasi-experimental	Posttest only, Between Group- Design	Strategic	Dragon Naturally Speaking Professional 5	Quantitative	STT significantly increased the length and decreased the surface errors of narratives for less fluent writers. STT did not significantly improve text quality.
Jeffs et al. (2006)	USA	8 (8)	9-14	Explorative	Interviews and observations	Strategic	Dragon Naturally Speaking Preferred	Qualitative	All the children in the study liked using speech-to-text software. Parents were beginning to realize that, when given the right tools, their child could be successful in reading and writing activities.
Noakes et al. (2019)	USA	3 (3)	9, 14 and 15	Quasi-experimental	Alternating Treatments, Single-Case Design	Strategic	Dragon Naturally Speaking	Quantitative	All participants significantly increased total words written, words spelled correctly and correct writing sequences, compared to the handwriting control condition.
Nordström et al. (2019)	Sweden	59 (59)	Grade 4, Grade 8 and upper secondary	Explorative	Cross-sectional	Strategic	iPad 2 or 3	Mixed	Students with reading difficulties could use writing apps (for example STT) in portable tablets to produce text in an applied school setting.
Ok et al. (2020)	USA	95 (95)	Grade 4 - 8	Explorative	Cross-sectional	Strategic	iPad	Mixed	Students across grades had positive perceptions about using STT. It was especially helpful for students who struggled with spelling and supported some, but not all, students while drafting text.
Svensson et al. (2021)	Sweden	149 (149)	Grade 4, Grade 8 and upper secondary	Experimental	Pretest-posttest, Between Groups- Design	Random assignment	SayHi	Quantitative	Both the intervention and control groups improved as much in 1 year as did the normed population. However, gains did not differ between the groups directly after the intervention or at 1 year of follow-up. 50% of the students and their parents reported an increase in motivation for schoolwork after the intervention.

[1] LD = Learning difficulties [2] NLD= Without learning difficulties

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Table 3. Grey Literature Included in the Review

Study	Country	Sample (LD[1])	Age	Approach	Design	Sampling	SR-Software	Method-ology	Key Findings	Format
Nisbet & Wilson (2002)	Scotland	32(32)	13-16	Explorative	Cross-sectional	Strategic	Dragon Naturally Speaking 4 or 5 and IBM ViaVoice Millennium Pro 7	Mixed	The success of introducing speech recognition in schools depends as much on school and staff resources, as on the skills of the individual student.	Report
Nisbet et al. (2008)	An updated report and guide for practitioners based on the same design, approach, and sample as the report by Nisbet & Wilson (2002)						Dragon Naturally Speaking Preferred Version 9	Mixed	Training sessions varied depending on the reading and ICT skills of the students. Motivation to use STT tended to be rated by the pupils as " good" or " excellent", and there was little difference between successful and unsuccessful students in relation to motivation.	Report
Mader (2007)	USA	3(3)	11, 13 and 14	Quasi-experimental	Alternating Treatments, Single-Case	Strategic	Dragon Naturally Speaking Preferred Version 8	Mixed	Findings suggest that STT can assist students with learning disabilities to produce better written products as they circumvent paper-pencil writing. Students are empowered to express their ideas in written form.	Disser-tation
Lawson & Nisbet (2016)	Scotland	39(39)	10-17	Explorative	Cross-sectional	Strategic	Dragon Naturally Speaking Pro 13	Mixed	Key advantages reported: Pupils overcome concerns about spelling; it provides independence and self-esteem, and is quicker than writing by hand or typing. Key disadvantages reported: Did not work for pupils with indistinct speech and some pupils reported that they experienced negative pressure to produce text	Report
Levine et al. (2022)	USA	120(73)	14 - 17	Explorative	Sequential equal status mixed methods design	Strategic	Google Documents	Mixed	STT can serve as an accessible alternative mode of composition for some high school students and may be especially useful for students with writing related LDs.	Preprint

[1] LD = Learning difficulties (or receiving special needs education)

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Table 4. The Areas of Interest in the Peer-Reviewed Studies

Areas of Interest and Study Variables		Higgins & Raskind (2000)	MacArthur & Cavalier (2004)	Quinlan (2004)	Jeffs et al. (2006)	Noakes (2019)	Nordström et al. (2019)	Ok et al. (2020)	Svensson et al. (2021)
Writing related skills	Word recognition	X							X
	Spelling	X							
	Reading comprehension	X							X
	Listening comprehension								X
	Phonological deletion	X							
	Orthographic choice	X							X
	Semantic choice	X							
	Metacognitive ability	X							
	Memory	X							X
Text assessment	Holistic text quality		X	X					
	Length		X	X		X			
	Vocabulary		X			X			
	Total errors		X	X					
	Unknown words		X						
	Correct writing sequences					X			
Writing process	Planning words			X					
	Error correction			X					
	Revising time		X						
	Planning time		X						
	Composing time		X	X					
Technology	Accuracy of STT		X	X					
	Drop-out	X	X						
Experiences	Student motivation						X		X
	Student learning						X		
	Tablets as ass.tech.						X		
	General opinion		X		X			X	
	Preferred modality		X						
	Strengths		X					X	
	Weaknesses		X					X	
	Frequency of use							X	
	STT's impact on writing				X			X	
	Need for support				X				

Figure 1. Flow Chart of the Screening Process for Peer-Reviewed Articles
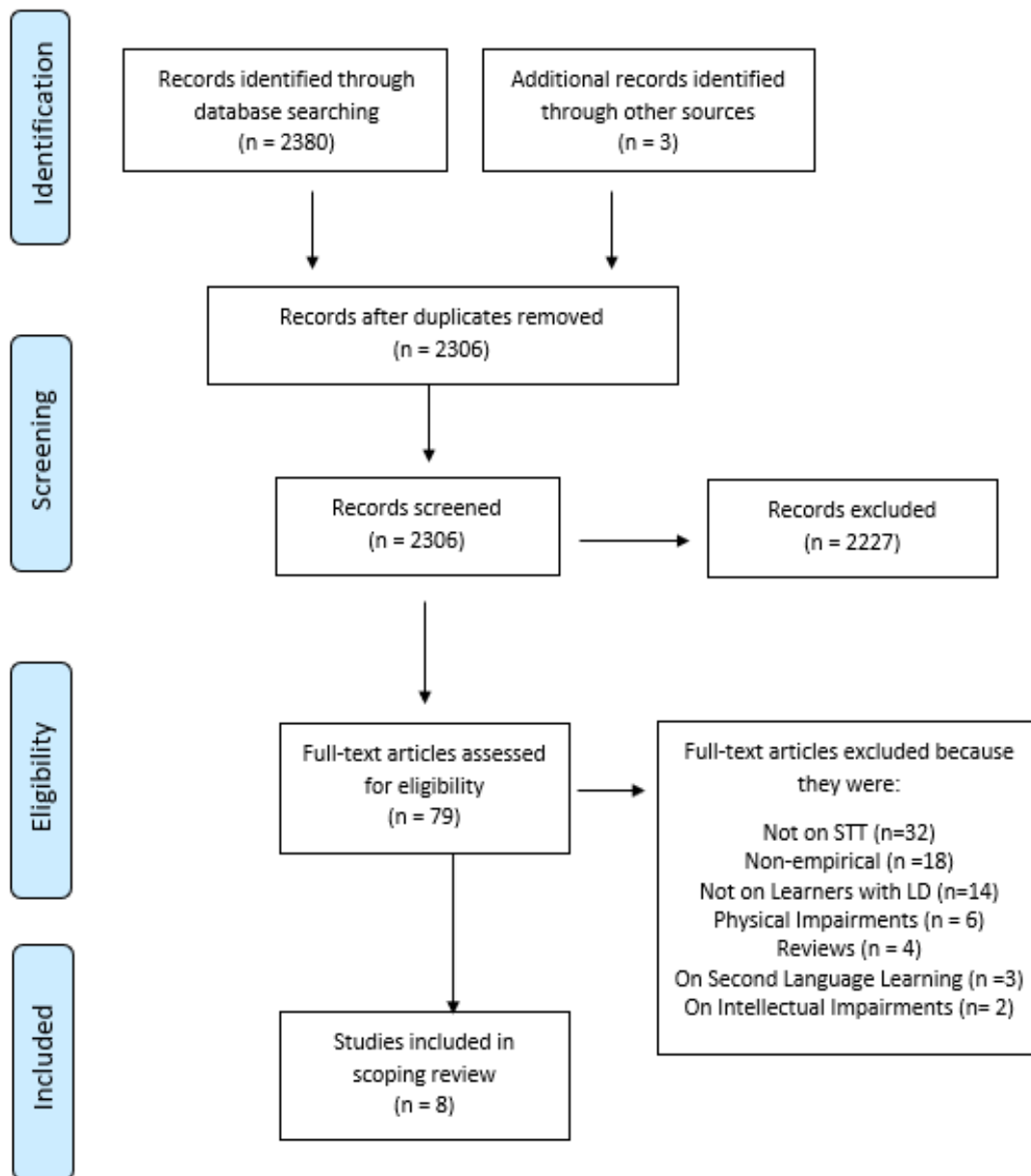
**Speech-to-Text Technology as an Inclusive Approach: Lower Secondary Teachers'
Experiences**

Abstract

Speech-to-text (STT) technology enables pupils to write using their voice. This qualitative study
explores six teachers' experiences with introducing STT technology in a whole-class
environment at a Norwegian lower secondary school. The aim was to explore the benefits and
challenges of using STT as an inclusive approach for writing instruction in lower secondary
education. The teachers in the study stated that most of their pupils found STT useful when
beginning longer writing assignments (for example, as an aid for brainstorming and drafting) and
producing texts in foreign languages. Reported challenges were pupils distracting each other,
inaccuracy of the technology, improper use, and pupils whispering because they were too
embarrassed to speak out loud. The teachers' views were initially consistent with a broad
definition of inclusion, as they saw the educational opportunities of introducing STT to the
whole class. However, after implementation, they were concerned with structural challenges,
including   formal assessment of writing and individual adaptation of the curricula, which
suggests a narrow interpretation of inclusion.

A major challenge in education concerns how to create an inclusive learning environment for all learners. Both the UNESCO Salamanca Statement (1994) and UN Convention on the Rights of Persons with Disabilities (United Nations, 2006, Art. 24. 2b) have been ratified to ensure that persons with disabilities have access to an inclusive, high-quality, free, and equal education. According to Haug (2017), a narrow definition of inclusion concerns education only for pupils with disabilities, while a broad definition addresses education for all pupils. Chambers (2020) argues that assistive technology can promote greater access to integrated settings, particularly with respect to reading and writing. However, there is little overlap between research on educational technologies used in full-class environments and technology used to support literacy in special education interventions (Pandya & Avila, 2017).

Despite limited research on assistive technology in inclusive settings, studies have shown both benefits and challenges of these technologies for pupils with varying abilities in reading and writing. For example, Silvestri et al. (2021) found that some learners with reading and writing difficulties benefited from assistive technology use. The results showed that individuals with dyslexia who had poor decoding skills but good listening comprehension experienced greater benefits than did other pupils with reading difficulties. In a study on writing technology use among 27 pupils with dyslexia, Mossige et al. (2021) found that approximately 30% of pupils introduced to custom-made assistive technology chose not to use it because they lacked technical support or perceived it as disruptive rather than helpful.

Speech-to-text technology (STT) has traditionally been seen as an assistive technology designed specifically for pupils with learning difficulties (MacArthur, 2009). STT converts spoken language to written text and has been available since the early 1990s as an assistive technology for pupils with a documented need through licensed software, such as Dragon Speak and IBM Voice Type (Ok et al., 2020). Speech recognition has radically improved since the earliest versions of STT software, providing improved accuracy and transcription of continuous speech (MacArthur, 2009). Since 2015, STT's integration into popular devices and software like Apple's iPad, Google's Chromebook, and Microsoft's Office have made it available to almost all pupils and teachers. Despite this increase in availability, there has been scant research examining the use of STT in educational contexts (Evmenova & Regan, 2019; Perelmutter et al., 2017).

In this study, a group of researchers observed and interviewed six teachers who were encouraged to introduce all pupils at a Norwegian secondary school to STT technology during writing assignments. The teachers were authorized to determine how and to what extent STT was to be implemented; however, they were also instructed to introduce the technology in a full-classroom environment. The researchers aimed to explore STT as an inclusive approach in lower secondary education and examine teachers' experiences with the technology during writing activities. The following research question guided this study: What benefits and challenges are inherent to STT as an inclusive approach for the teaching of writing in lower secondary education?

Theoretical perspectives

Aiming to show the multitude and hierarchy of definitions of inclusion within education, Göransson and Nilholm (2014) analyzed inclusive education research and identified four categories of definitions. Articles using the first level of definitions (Category A) describe inclusion as the placement of pupils in need of special support in general education classrooms. Category B articles consider inclusion as meeting the social and academic needs of pupils with disabilities in need of special support. Articles in Category C argue that inclusion should also meet the social and academic needs of all pupils, while Category D articles consider inclusion both to concern all individuals and be characteristic of a culture. According to the Category D definition, inclusion is affiliated with the notion of community and creating a mindset that values subjugated knowledge, equity, justice, and diversity. Relating Göransson and Nilholm's framework to Haug's (2017) definitions of inclusion as either narrow or broad, articles in Categories A and B are considered by Haug to fit the narrow definition of inclusion, while Categories C and D reflect a broad definition. To employ this theoretical framework, findings are presented according to Göransson and Nilholm's categories. Their theoretical framework will be employed when discussing STT's benefits and constraints according to different aspects of inclusion.

The broad and narrow dichotomy of inclusion also exists in research on educational technology. Researchers may apply a narrow perspective to consider how different digital approaches enhance access and participation for pupils with special educational needs (e.g., Foley & Ferri, 2012). Thus, a narrow perspective is prevalent in studies of assistive technology,

which concentrate on equipment or software used to improve or maintain the functional capabilities of individuals with disabilities (Individuals with Disabilities Act, 1990). Assistive technologies may play a primarily compensatory or adaptive role in education, whereas educational technology offered to all pupils is intended to enhance learning in general or within specific curricular areas. When employing a broad definition of inclusion, research on educational technology may focus on how all pupils benefit from the technology rather than a particular aspect of inclusion. For example, Haug and Klein (2018) investigated STT as a writing strategy for a heterogeneous group of grade 5 pupils in general education, and Shadiev et al. (2017) studied STT's influence on learning performance, attention, and mediation among 30 university students.

Researchers have proposed Universal Design for Learning (UDL) as a means of addressing the dilemma of how educators can create inclusive learning environments by introducing technology to all learners. Rose et al. (2018) created the UDL framework to ensure educational equity for learners who had previously been presented with a one-size-fits-all approach to educational activities and material. The framework's formulation aims to optimize teaching and learning for all by providing multiple means of engagement, representation, action, and expression (Rose et al., 2018). Some researchers have criticized UDL for considering special education approaches suitable for all learners. For example, Kumar and Wideman's (2014) study of UDL-inspired coursework in higher education showed that applying the framework increased teachers' workload in order to fulfill UDL principles. Loreman (2017) argued that inclusive approaches like UDL differ from previously favored special education approaches based on specific processes and schedules for teaching and adapted to a given situation and pupil. Loreman (2017) supported the claim that inclusive pedagogical approaches demand more from teachers than previous approaches in terms of professional skill, judgment, flexibility, and willingness to grow as professionals.

Methods

Setting and Design

The current study has employed a longitudinal, exploratory design using qualitative methods. It is part of a larger project incorporating both quantitative and qualitative approaches used to

examine the introduction of STT in lower secondary school classrooms with diverse learners. The setting was a lower secondary school with 92 pupils in grades 8–10, situated in southern Norway. A team of researchers and the Norwegian National Service for Special Needs Education (Statped) collaborated on the project. The researchers were responsible for gathering data, and Statped employees developed the digital course and led training sessions with teachers and pupils. All 14 teachers at the school took part in the digital course and were invited to participate in the study, to which six teachers agreed.

Ethical Considerations

The research group followed guidelines and recommendations from the Norwegian Centre for Research Data. All participants received and signed consent forms after having been informed that participation was voluntary. All personal information was kept anonymous, and participants were informed that they could withdraw at any time prior to the publication of findings.

Participants

The participants included three male and three female lower secondary school teachers. Two teachers had less than 5 years of experience; two had between 5 and 15 years of experience; and two had more than 20 years of experience. They taught different subjects, including language arts (Norwegian), foreign languages (English, German, French, and Spanish), mathematics, physical education, religion, social science, and natural science. One participating teacher also held the position of assistant principal. Two participants had no prior experience with STT technology. The other four had used it to some extent during writing activities, either didactically with pupils or on their own (e.g., to write emails, meeting notes, or personal "to do" lists).

Data Collection

Data were collected in three phases in the form of focus group interviews and implementation plans made during the pre-intervention period (phase one), full-class observations during the intervention (phase two), and individual teacher interviews after the intervention (phase three). The author observed six lessons during the intervention period (two lessons per grade level). Lessons were observed at the beginning of the implementation period in weeks 2 and 5. The original study design underwent several alterations due to national Covid-19 pandemic restrictions and a shortage of teaching staff. For instance, observations scheduled for weeks 8

and 10 were canceled, focus group interviews were conducted with only two pairs of teachers, and the six individual interviews scheduled to take place immediately after the implementation period were postponed until the following semester.

STT Intervention

Prior to introducing STT in the classrooms, two project members with expertise in special education and assistive technology led a 60-minute training session with the teachers, followed by a 45-minute instructional session for the pupils in each class. During training sessions, teachers and pupils were instructed on how to activate STT and use voice commands to produce punctuation marks, such as "full stop" or "comma." Participants had the opportunity to ask questions and try out STT during brief writing activities. When using STT on their laptops, pupils activated speech recognition in Microsoft Office Word. Microsoft had made STT available in Norwegian approximately four months prior to the implementation period (October 2019). STT has been available in Norwegian on iPads since the launch of Apple's iOS 9 in 2015. The pupils activated the STT feature using the keyboard settings on their iPads. The pupils chose which applications to use, including Pages, Notes, Book Creator, iThoughts, and Microsoft Word.

Both teachers and pupils had individual iPads and/or laptops. For digital assignments, the school used two learning management systems: Showbie and It's Learning. The research project provided pupils and teachers with noise-reducing headphones with microphones and iPad covers with integrated Bluetooth keyboards. During pre-intervention interviews, teachers were asked to make suggestions about how STT could be introduced in their classroom, including which subjects were most appropriate for implementing STT and in what timeframe. Based on these suggestions, a timetable was created for each class using the digital platform Showbie. Prior to the intervention, teachers filled out a timetable (see Table 1) indicating the time allotted to STT activities per subject area as well as the chosen lesson content and assignments. The teachers provided information on whether pupils had used STT as planned and how they experienced the teaching sessions during the 10-week intervention period. The teachers from each grade level created a collective plan for their group of learners (Table 2).

Analysis

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Data were analyzed from different sources, including transcriptions from teacher interviews, logs of comments, timetables from Showbie, and observation notes made during training sessions and lessons. The process of corroborating data from different individuals, types of data, and methods of data collection, known as *triangulation*, was used to enhance the study's accuracy and credibility (Creswell, 2014). Göransson and Nilholm's (2014) hierarchy of definitions of inclusion was used as a broad framework for organizing data for further analysis. Although Göransson and Nilholm (2014) based their categories on definitions of inclusion in the literature, it is useful to apply this framework to the analysis of teachers' experiences with inclusion. Teachers' actions when implementing inclusion, and their manner of describing these actions, reflected their understandings of the phenomenon, which may or may not correspond with broader theoretical perspectives, such as those of Göransson and Nilholm (2014) and Haug (2017). In either case, such an approach is likely to enrich the knowledge base.

Data were first sorted according to the previously defined four categories: placement (A), meeting the academic and social needs of pupils with special needs (B), meeting the academic and social needs of all pupils (C), and aiming to create a mindset that values diversity (D). Within this framework, the data's emerging themes were coded into subcategories. Given that participants agreed to introduce STT to all pupils in whole-class settings as a premise for participation in the project, the placement issue (A) did not emerge as a prominent theme or concern. Therefore, the main findings are structured and discussed in relation to Categories B, C, and D.

Findings

STT for Pupils with Reading and Writing Difficulties

Some teachers had prior experiences with STT, which influenced their expectations and understanding of using the tool with their whole class. Three pupils with reading and writing difficulties had previously been provided with STT. However, two of these pupils had not wanted to use it, while the third had used it throughout the three years of lower secondary school, including on their final exam. During interviews and intervention planning, teachers mentioned the fact that STT was allowed as a test accommodation only for learners with special needs. While making the implementation plans, one grade 10 teacher specified that they had a lot of

material to cover before the final exam. The teacher was hesitant to introduce STT as a writing tool for all pupils because it would not be available to all on the final exam.

One teacher described his experience with a pupil with dyslexia who had previously been introduced to STT. The teacher reported that the pupil was entitled to receive special education, as he had not developed sufficient orthographic encoding skills in English; consequently, he made many spelling errors when attempting to apply the phonemic rules of Norwegian to English texts. This pupil was more fluent when speaking English than when writing it, enabling him to produce longer texts through using STT. Yet, the teacher emphasized the difference between "getting started" with STT and continuing to use it in everyday writing activities. As mentioned, although the school had introduced SST to other pupils with similar special educational needs, they chose not to adopt it as an assistive technology. He explained:

> Speech-to-text technology is incredibly easy to get started with. It's quite accessible because you activate it, start speaking, and look—it's writing what you're saying! However, the challenge is to exploit its potential, to make it a tool that [pupils] will actually use. That's a bit harder.

The teacher further explained that the pupil who continued using STT was more willing and able to edit his text compared to other pupils with reading and writing difficulties. The teacher noted that the pupil discovered that STT allowed him to produce a draft that could be improved using additional assistive tools, for example spellchecks.

STT as a Tool for all Pupils

Three prominent themes emerged relating to whether STT is an inclusive approach that meets the academic and/or social needs of all pupils: (1) pupil acceptance, (2) curricular content, and (3) assignments.

Pupil Acceptance

Findings revealed a perception among teachers that pupils' acceptance of STT and their success with using it were linked to each pupil's individual aptitudes, such as problem-solving skills, flexibility, and willingness to take on new tasks. Most teachers considered STT to be a technology that could provide new opportunities for all pupils and, for example, activate them to

learn background knowledge, communicate ideas, and create first drafts. However, one teacher explained that pupils who mastered typing reported that it was annoying to be forced to learn a new method that they perceived as both time-consuming and less accurate. This teacher described how pupils who generally mastered new skills quickly also tended to master the use of STT without difficulty. He explained that skilled writers complained less about delays or errors (e.g., STT mistakenly generating homophones) and that they quickly tried again when something went wrong. Conversely, learners who were less motivated at school were less likely to give STT a chance. He explained:

> I think it's because they struggle a bit in general with school assignments, and then they experience another thing [STT] that does not work optimally, so they lose motivation faster compared to others who are more willing to try different approaches.

Curricular Content

A participant argued that STT could be more appropriate in writing-intensive subjects such as language arts. She also considered it relevant for use in religion or social science because some pupils found it challenging to get their ideas down in writing in these subject areas. She described how they would have several ideas when they discussed different topics orally but struggled to write down their reflections and arguments. Another teacher suggested that STT could be a suitable tool for learners who often write long texts:

> I know that several pupils write a lot, and maybe it'd be easier for them … the way I experience speech-to-text is as an aid that may provide… the opportunity to speak more freely and directly into a document. I see it as an opportunity, a portal into new methods of learning.

Although opinions varied, some teachers reported that STT could help activate pupils' background knowledge and enable them to communicate ideas without having to worry about grammar and spelling. While not all pupils needed this assistance, the teachers believed that all pupils could benefit from it.

Assignments

The analysis revealed little agreement among participants regarding the appropriateness of STT for different kinds of assignments or classwork. One teacher argued that it had worked well with shorter writing tasks, for example, when pupils were required to answer questions from a text that they had read. As noted above, other teachers considered STT a suitable tool for starting rough drafts. One teacher used STT as a digital brainstorming tool during the implementation period and saw it as an aid for process-oriented writing. She explained that watching pupils write a draft using STT reminded her of how she used to create drafts when producing handwritten texts during her own time as a pupil.

> I've been thinking that we're going back to the way I used to work when I was writing a text, back when the main focus was on the draft. Lately, I think there's been too little focus on planning and developing a text… Now [with STT]. your teacher can say that you have to plan the text.

Several teachers highlighted the importance of planning and expressed that the main benefit of using STT was that pupils were able to make a first draft without having to worry about spelling. A language teacher explained that some of his pupils struggled to write drafts in English when they started lower secondary school, resulting in their making notes in Norwegian before writing longer texts in English. He believed that most pupils could benefit from using STT for writing drafts and taking notes in foreign languages when they knew how to pronounce a word yet struggled with spelling it.

In the focus group interviews, two teachers discussed whether texts written through using STT demonstrated learners' oral or written skills. They considered it both an opportunity and a dilemma that the line between speaking and writing was less evident when pupils used their voices to write. Another teacher argued that STT provides an opportunity to discuss rules and norms for formal and informal language as well as what is expected when producing written assignments within different genres.

Creating Acceptance of Diverse Communities

Several findings show how STT may contribute to or limit access to inclusion with respect to creating learning communities that value diversity. The teachers considered STT to be an approach that could reduce barriers to participation by allowing more pupils to take part in

writing activities. In their reflections on using STT in a whole-class environment, they saw STT as an opportunity when pupils were working on collaborative tasks; at the same time, they experienced challenges with respect to group composition, increased distractions, and improper use of technology in these settings.

Opportunities for Collaboration

With respect to creating new opportunities for collaboration, one teacher described how using STT had influenced the way he taught writing:

> Traditionally, writing's been considered a quiet activity, but that doesn't work for me. I want the pupils to work together and develop their ideas together. So, they need different phases of writing, with one phase being a bit noisier than others because they can use STT during it. Afterwards, they can edit their texts in a quieter setting on their own.

Several teachers offered similar statements, indicating that STT could give pupils an opportunity to write together while including pupils who would experience barriers if they had only a keyboard or pen available for them to use.

Challenges to Inclusion

The teachers also reported challenges when introducing STT in a whole-class environment. These challenges included pupils distracting each other, improperly using technology, and whispering because they were too embarrassed to speak out loud, resulting in further technical difficulties. A teacher highlighted the importance of considering group constellations when placing pupils in groups for writing assignments using STT.

> The groups can't be too large, and you have to consider which pupils work well together. Some pupils make comments, and you have to have someone in each group who'll take charge and make sure that everyone stays on task, or else they'll start using it inappropriately, at least when they're testing it out for the first time.

Another teacher commented that pupils who are hesitant to speak up should be placed in the same group to avoid being intimidated by more outspoken pupils. A third teacher preferred smaller groups of pupils in several more private locations that allowed pupils to speak out loud and use STT more actively. This teacher noted, "With the full class present, they only whispered,

and then they had to repeat everything several times." This finding was also evident during observations, in which some pupils seemed embarrassed to speak out loud when they were working on individual writing tasks while sitting in the same room. Some pupils "stalled," which limited the length of the texts that they produced.

Another challenge was related to the introduction of STT in lower secondary education. As one teacher explained, "When they start in lower secondary school, they have to be able to write longer texts, and they're expected to argue their point of view." The teachers considered it too late to introduce STT at this stage, as most pupils had already acquired efficient handwriting and typing skills; in addition, their focus had shifted from spelling and creating coherent texts to communicating subject-matter content. Therefore, most of the participants recommended introducing STT earlier, for instance in grades 5–7 (ages 10–12).

Discussion

Providing opportunities for all

This study aims to explore the potential of STT as an inclusive approach for writing instruction in lower secondary education. Fundamental questions exist concerning what teachers and schools may gain or lose when shifting to new technologies such as STT. The difficult balance between a narrow and broad approach to inclusion became evident through teachers' reflections when they were describing the potential of STT for all pupils. The teachers reported the main benefits of STT to be the opportunity for pupils to discuss conventions of spoken and written language, make drafts using oral skills, and acquire a new approach to learning. These findings align with UDL principles as well as a broader understanding of inclusion, which states that inclusive technology should provide learning opportunities for all pupils (Göransson & Nilholm, 2014; Haug, 2017). Rose et al. (2018) argue that the goal of UDL is not simply to help learners master a specific body of knowledge or skills but to master learning itself. UDL aims for educators to create learners who know how to learn regardless of their strengths and weaknesses (Rose et al., 2018). According to the Norwegian language arts curriculum, by year 10 pupils are expected to be able to "inform, relate, reason and reflect in various oral and written genres and for different purposes and adapt to the receiver and the medium" while having the capacity to "express themselves in different genres and experiment with genres in a creative way" (The Norwegian

Directorate for Education and Training, 2020). In a broad sense, then, teachers considered STT to be an approach that could be useful for all pupils working toward mastery of these lofty goals contained in the lower secondary curriculum.

Social and academic needs

According to the second-highest level of inclusion in Göransson and Nilholm's (2014) hierarchy, inclusion benefits both the academic and social needs of all pupils. The teachers reflected upon structural constraints in the Norwegian Education Act (2006) when planning to introduce STT to all pupils. Currently, STT is not allowed on formal written exams in secondary education in Norway unless the pupil has a documented need for exam accommodations. Parents of pupils who are not able to demonstrate their competence on written exams must apply to the school principal, who must evaluate whether STT or other assistive technology can enable the pupil to demonstrate their competence without providing them with an unfair advantage or making it impossible to test their skills in the relevant competency areas (Regulations to the Education Act, 2006). The formal limitations of the Norwegian Education Act contrast with the UDL framework, which states that all learners should be provided with flexible options to express their skills, knowledge, and understanding in assessment situations (Rose et al., 2018).

The teachers described varying degrees of the academic benefits of STT for their pupils. They reported that skilled writers complained less about accuracy errors while less motivated writers were less likely to give STT a chance. De Smedt et al. (2018) highlighted the close relationship between low writing achievement and a lack of academic motivation. In relation to reading, a pattern emerged that was consistent with the biblically derived concept of the Matthew effect, which states that the "rich get richer, and the poor get poorer" (Stanovich, 1986, p. 360). Thus, pupils who struggle with decoding may have lower expectations when introduced to new writing activities because they tend to produce more spelling and grammatical errors and spend more time completing tasks. Despite being introduced to the same technology (e.g., STT), pupils nevertheless approach writing activities with different experiences, motivation, and likelihood of success.

Both classroom observations and teacher interviews revealed that pupils were embarrassed to use STT in a whole-class environment, and teachers encouraged pupils to find

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remote locations. These findings are consistent with another exploratory study by Ok et al. (2020) on the use of STT for writing activities among pupils with high-incidence disabilities. In that study, teacher-reported challenges included finding the right environment (e.g., a quiet place), pupil distractions, improper use, as well as resistance and anxiety among pupils surrounding STT use. Given that teachers must create classroom climates that are conducive to learning, acceptance of new technology is heavily influenced by the degree to which this technology damages the social and physical harmony within the classroom. A primary intention behind introducing STT in a whole-class environment has been to avoid the potentially negative impact of separating children for the purpose of "specialized" interventions. However, if STT causes disruption, isolation, or embarrassment, the technology may function poorly as an inclusive approach.

Creating inclusive learning communities

The teachers saw STT as a tool that could provide more pupils with an opportunity to participate in writing activities. By increasing pupils' participation in and access to writing, STT may contribute to creating more inclusive learning communities that value diversity. In other words, STT may help create flexibility and reduce learning difficulties. In accordance with the UDL framework, disabilities are not inherent in individuals but rather are created in an interaction between the learner and the learning environment (Rose et al., 2018). Thus, improving the interaction between pupils and their environment through the use of assistive technology may reduce barriers to learning and inclusion. Yet, teaching professionals may find it difficult to know in advance which pupils will benefit from assistive technology. With a universal approach, all pupils are provided with an array of alternatives (Haug, 2017). These experiences may alter pupils' perceptions of the technology. Göransson and Nilholm's (2014) "highest level" of inclusion is not limited to the creation of communities, but also refers to the creation of a more tolerant society. While STT alone cannot create more accepting, diverse, and inclusive learning environments, it may alter ideas of what writing is in an educational context and increase acceptance of alternatives, provided that pupils are introduced to the technology at an appropriate stage in their development. Currently, we lack sufficient research to identify exactly when that point might be. However, the teachers in this study expressed that lower secondary school is not

the appropriate point given the demands made on pupils at this stage of their education and the literacy progress that many have already achieved.

Conclusion

The study highlights that implementation of STT technology challenges different aspects of inclusion which teachers and school leaders need to take into consideration. The participating teachers primarily considered SST to be an assistive technology that was useful for pupils with writing difficulties. At the same time, they noted that STT offers opportunities for all pupils to participate in collaborative writing tasks, discuss norms for formal and informal language, and produce first drafts without having to worry about spelling. However, STT was only available to pupils with a documented need for assistance on the final exam. Therefore, the teachers did not consider STT to be equally available and beneficial to all pupils. When new approaches to writing appear, teachers and school leaders are required to consider the extent, aims, and consequences of introducing (or not introducing) the approach. These findings provide educational professionals and researchers with insights into the complexity of introducing STT as an inclusive approach. The findings show that STT provides academic opportunities for most learners; at the same time, it is described as a disruptive and embarrassing element in a whole-class environment. The conflict of interest between fulfilling pupils' social and academic needs became particularly evident when teachers argued that pupils could benefit from being placed in smaller groups and more private locations when using STT. This is an argument against introducing STT in a whole class-environment. However, if the smaller, secluded groups consist of pupils with and without writing difficulties, it can be considered an inclusive approach according to Haug's (2017) broad interpretation of inclusion. More research is therefore needed on the implications of introducing STT as a writing approach in primary and secondary education.

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Table 1. Example of an implementation plan from grade 9.

When (week)	1	2	3	4	5	6	7	8	9	10
What	Introduction	Test out		Winter Holiday	Make dispositions, drafts and mind maps			Write longer texts		
# Lessons (45 minutes)	2	4	4		2	2	2	4	4	4
Subject		Norwegian English Social Science Science			History English Science			Norwegian History:		
Theme		English: Slavery Social Science: Russian revolution Science: Electricity			History: American history Science: Experiments			History: Slavery		
Assignment		Answer questions from a short text			Prepare for a longer assignment			Write longer assignments		
Completed (Yes/no)										
Comments										

Table 2. Average number of lessons and subjects planned and having used Speech-to-Text technology.

	Grade 8	**Grade 9**	**Grade 10**
Planned average number of lessons (45 min.) using Speech-to-Text	7	3	3
Average number of lessons (45 min.) using Speech-to-Text during the intervention	6	4	2
Subjects	Language Arts, English and Social Science	Language Arts, English and Social Science	Language Arts and Natural Science

An exploratory study on the use of speech-to-text technology as a writing modality

for pupils with low writing achievement in Norwegian lower secondary education

Abstract

Six Norwegian lower secondary school pupils (ages 14-15 years) with low writing achievement participated in a stimulated recall study aimed at exploring how pupils write and experience writing with speech-to-text (STT) technology in an educational context. The study employed an exploratory design, collecting data from screen recordings and stimulated recall interviews. The screen recordings were captured while the adolescents wrote a reflective text in Norwegian, using STT and keyboard. Findings showed that the pupils were able to produce a reflective text using STT technology while experiencing both benefits and challenges due to the technology. Benefits included the opportunity to use words that they did not know how to spell and verbal skills to produce arguments in writing. Challenges were mainly related to transcription errors and technological inaccuracies. Findings suggest that technological issues need to be addressed and sufficient planning and instruction is necessary before STT can be a truly beneficial tool for adolescents with low writing achievement in secondary education.

Introduction

Technology options for writing instruction have largely been limited to providing a choice between writing by hand and writing on a keyboard. Due to technological advances, speech-to-text (STT) technology, previously expensive and available only to pupils with documented needs, has now been integrated into writing software from Google, Microsoft and Apple. Arcon et al. (2017) suggests that if pupils can dictate rather than transcribe, constraints pertaining to spelling and orthography would be reduced, and their texts would increase in quantity and quality. Indeed, research indicates that pupils with learning difficulties can produce higher-quality compositions when dictating texts to a scribe compared to writing by hand or typing (De La Paz & Graham, 1997).

In an exploratory study of usage patterns and perceptions of writing with STT, Ok et al. (2020) studied American pupils with high incidence disabilities in grades 4–8. Although the findings showed that pupils across all grades reported positive experiences of writing with STT, the younger pupils used it more frequently compared to older pupils. Moreover, pupils with spelling difficulties and strong oral skills tended to be more willing to use STT and used it more often. Pupils who were good spellers but had expressive language difficulties, such as speech impairments or accents, felt that STT did not aid them in writing. The teachers reported that the key benefits of using STT for pupils with high incidence disabilities were to overcome hurdles with writing tasks, to write more independently, generate more text, and provide more opportunities to write and improve pupils' confidence in writing (Ok et al., 2020). Very little research has been conducted on pupils with low writing achievement using STT as a writing modality in secondary education (Matre & Cameron, 2022). However, there have been

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published dissertations on the use of STT, and other kinds of assistive technologies, targeting pupils with reading and writing difficulties in the Nordic countries (Kraft, 2023; Svendsen, 2016). In addition, there are promising results from research on the use of STT among pupils with learning difficulties in the United States (Ok et al., 2020; Quinlan, 2004) and Sweden (Kraft et al., 2019; Svensson et al., 2021). Yet, no studies have currently been published on the use of STT in the Norwegian educational context. Therefore, the aim of this study is to explore how pupils with low writing achievement write and experience writing with STT in a Norwegian educational context. The following research questions have guided the study:

1.   How do pupils with low writing achievement approach the task of writing a reflective text using STT?

2.   How do pupils with low writing achievement experience writing with STT?

Writing: Cognitive, Social and Technological Dimensions

Aiming to describe the complexity of the cognitive processes involved in writing, MacArthur et al. (2016, p. 1) presented writing as a 'complex social and cognitive process that requires shared understanding with readers about purposes and forms, knowledge of content, proficiency in language, and a range of skills and strategies, as well as motivation'. That writing is considered both a social and a cognitive process has been realised through different areas of educational research. From sociocultural studies emphasizing the communicative aspects of writing (Bazerman, 2008, 2016) to neurological or linguistic studies aiming to map and understand the underlying cognitive processes involved in writing and the development of writing-related skills (Hayes & Flower, 1980; MacArthur & Graham, 2016).

In educational research, theoretical frameworks have traditionally described either the cognitive processes underlying the development of writing skills or the social practices involved in writing. For example, the developmental model *The Simple View of Writing* by Berninger and Amtmann (2003) describes writing as three cognitive processes – transcription, self-regulation, and text generation – that are governed and constrained by working memory. Sociocultural models of writing move beyond cognitive processes and consider writing a mode of social action involving both readers and co-authors (Prior, 2006). This is particularly relevant in an educational context, as writing seldom is a solitary endeavour; rather, it is usually structured, guided and evaluated by teachers and peers. In recent theoretical models, both social and cognitive elements of writing have been included. In the revised Writer(s)-Within-Community (WWC) Model of Writing, Graham (2018, p. 258) proposed that writing is 'shaped and bound by the characteristics, capacity, and variability of the communities in which it takes place and by the cognitive characteristics, capacity, and individual differences of

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those who produce it'. The WWC model is twofold: one part describes the basic components of the writing community, while the second part shows the cognitive mechanisms involved in writing. Even though the model is presented in two separate structures, Graham (2018) underlined that the two are connected and that writing is an interaction between the writer and the writing community.

The revised WWC model (Graham, 2018) highlights the cognitive mechanisms involved in writing, from control mechanisms to long-term memory resources, the production process and modulators of the writing process. However, the model also emphasizes that cognitive mechanisms are not entirely individual traits. When writers compose, they take into consideration future readers and assessors of their texts. According to the revised WWC model, readers and assessors are referred to as the writing community that also influences text composition with elements such as the community's collective, institutional expectations, the physical and social environment or goals. Thus, when analysing how adolescents approach and experience writing with STT in an educational context, it is important to consider both cognitive elements, such as transcription skills, attitudes towards writing and the ability to revise and reconceptualise, in addition to social factors, such as the abilities and opinions of the writing community and pupils' physical and social learning environment.

According to the Norwegian Language Curriculum (Norwegian Directorate for Education and Training, 2020), primary school pupils are expected to write texts with functional handwriting and using keyboard by the end of year 4 (age 8-9), and write fluently by hand and on keyboard by the end of year 7 (age 11-12). Pupils with low writing achievement in Norwegian lower secondary education have not sufficiently mastered these goals and may not have acquired the mechanics of writing to a point of automaticity. Brandenburd et al. (2015) argue that pupils with low writing achievement

often have impaired working memory related to central executive function and the phonological loop. Having reduced working memory has been found to influence both writing fluency and text quality (Hayes & Berninger, 2014). Studies on the use of assistive technology have shown that pupils with writing difficulties may benefit from writing with STT (MacArthur & Cavalier, 2004; Quinlan, 2004).

Quinlan (2004) found that STT significantly increased the length of less fluent writers' texts and decreased the number of surface errors in their narratives. Yet, the texts written using STT were not of a significantly higher quality than the texts written by hand. Similar outcomes have been observed among children without reading difficulties. For example, Hayes and Berninger (2009) found that primary school pupils in grades 2, 4, and 6 showed an increase in the number of ideas generated as well as an enhancement of the quantity and quality of texts produced when dictating to a scribe compared to writing texts by hand or on a keyboard. However, the approach was not as effective for older pupils who had already developed solid handwriting and transcription skills (Hayes & Berninger, 2009). These findings may be related to Bereiter and Scardamalia's (1987) developmental model of writing which describes how writers mature from basic knowledge telling, to more advanced knowledge transformation. Writing as knowledge telling is characterized by idea retrieval and retelling, while knowledge transformation includes the interaction between planning, translating and reviewing ideas to make sure that the writer's ideas come across as the author intends (Bereiter & Scardamalia, 1987; Kellogg, 2008). One of the arguments for introducing pupils with low writing achievement to STT technology, has been that the technology can reduce barriers pertaining to spelling and encoding and allow the pupils to focus on planning and reviewing ideas, resulting in more advanced writing strategies, increased fluency and improved text quality (Arcon et al., 2017; De La Paz & Graham, 1997).

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Methods

The study employed an exploratory design, collecting data from screen recordings, pupil texts and stimulated recall interviews. The six pupils recruited for this study were already participating in a related research project aiming to explore STT as an inclusive approach in lower secondary education (Matre, 2022). The pupils were introduced to STT technology in January 2020 by their teachers and practiced using STT with their classmates for approximately four hours per week for 10 weeks, until March 12th, 2020. Due to the COVID-19 pandemic and consecutive home schooling, the stimulated recall sessions and interviews had to be postponed until eight months after the 10-week period (November and December 2020). The pupils reported that they had used STT to a very little degree during the home school period.

Participants

Six pupils in grades 9 and 10 (M = 14.98 years) in a rural area in Norway were invited to write a text by dictating to a computer. The pupils were allowed to type and make revisions on the keyboard, yet they were encouraged to write primarily by speech. The participants performed in the lower levels of the compulsory national reading test for grade 8, scored in the 30th percentile or lower on a standardized Norwegian spelling test (Skaathun, 2013), and were considered writers with low writing achievement based on teacher nominations. National reading test scores are presented according to five levels of mastery, where levels 1–2 are mastery below average and levels 4–5 are above average. The skill domains underlying writing and reading are closely related (Fitzgerald & Shanahan, 2000; Wengelin & Arfé, 2017), thus a group of pupils performing at the lowest mastery levels of both a standardized writing and reading test are likely to display low writing achievement. Demographic information and the

sample's results on the spelling test and mastery level on the national reading tests are presented in Table 1.

[Insert Table 1 about here]

Data Collection

Data collection was conducted in two parts. Part one consisted of a screen-recorded writing session, and part two comprised individual stimulated recall interviews. The use of more than one data collection method, also known as methodological triangulation (Noble & Heale 2019) was employed to enrich and validate findings. The pupils were divided into two groups and situated in a small classroom with desks placed in each corner. Two stimulated recall interviews started immediately after the writing sessions, while the remaining four were conducted consecutively within two hours of the writing session. Both the writing sessions and interviews took place during school hours.

Screen Recordings

In part 1, the pupils were given five minutes to plan and 15 minutes to write a reflective text in Norwegian using STT and keyboard. The pupils were encouraged to write using STT but were allowed to use the touchpad (mouse) and keyboard. They were also provided with noise cancelling headphones and used the STT software integrated into Microsoft Office Word 2019, which enabled screen recording in Microsoft Office PowerPoint 2019. The STT software had been available in Norwegian in Microsoft Office for approximately one year at the time of data collection. According to Yu and Deng (2015, p. 1), STT relies on building models from big data collected from real usage scenarios to make a system robust. The learning algorithms underlying Microsoft's STT were trained on a universal language model and adapted to Norwegian

using the Norwegian Language Bank's[3] dataset of speech and text. Compared to STT building on larger language corpora of English, Chinese or Spanish speech and text, the Norwegian dataset is significantly smaller and, thus, prone to produce more recognition errors.

The Writing Task

The topic of the writing task was social media's influence on adolescents. The pupils were provided with the following prompt: 'Do you think social media affects how adolescents behave? Reflect and argue your opinion'. Reasoning and arguing in reflective texts are part of the Norwegian lower secondary school curriculum (Norwegian Directorate for Education and Training, 2020). The influence of social media was considered a topic well known to the pupils and suitable for reflection. It is also central to the latest Norwegian Core Curriculum implemented in the autumn of 2020, which emphasises health and life skills as one of three interdisciplinary topics (Norwegian Directorate for Education and Training, 2020).

Stimulated Recall Interviews

Stimulated recall is an approach where the researcher presents authentic stimuli to research participants to acquire thoughts and experiences on an original situation (Vesterinen et al., 2010). The authentic stimuli were screen recordings of adolescents writing a reflective text using STT and keyboard. Video stimulated recall has been frequently used to explore how pupils or teachers experience specific events in education (Lyle, 2002; van der Kleij, 2021). It is a data collection approach related to the verbal protocol approach, where the researcher encourages the subject to think-aloud

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[3] An open-source dataset provided by the Norwegian National Library
https://www.nb.no/sprakbanken/en/sprakbanken/

during an activity to provide insight into cognitive processes. The verbal protocol approach has been applied in writing research (Hayes & Flower, 1981; Swain, 2006), and in research on writing technology for pupils with low writing achievement (Svendsen, 2016). In contrast to the verbal protocol approach, video stimulated recall allows the pupils to complete their task before they are encouraged to analyse and elaborate on their experiences.

To prompt recall of the situation, Lyle (2002) recommends that interviews should be conducted as soon as possible after recorded sessions. In this study, the pupils were presented with the recording within hours of writing and encouraged to describe their experiences. During the stimulated recall interviews the pupils were instructed to describe how they experienced writing with STT. Both the researcher and the pupils were able to pause the screen recording whenever they wanted to ask a question or comment. To prompt recall, the researcher asked open-ended questions, such as 'What happened here?' or 'Why did you stop here?'. After watching the screen recording of the writing session, the pupils were asked questions about how they experienced using STT for that specific writing task. They were also asked to describe challenges or advantages of STT versus typing or writing by hand. The interviews lasted between 21 and 39 minutes.

Analyses

Two kinds of analyses were conducted: (1) analyses of screen recordings and (2) analyses of stimulated recall interview transcripts. To be able to explore how the pupils wrote with STT (research question 1), variables that describe text production (e.g., words produced with STT, words typed, words removed, words per minute and accuracy) were registered from the screen recordings. See Table 2 for an operationalization of the variables describing the pupil's text production with STT and

keyboard. Only recordings of the 15 minutes of text production were analysed; thus, the five minutes of planning time were not included in the analyses. Measures from the final texts were also analysed, including variables such as final accuracy and final word count. Frequencies were registered by the author and a research assistant. To determine coding consistency, inter-rater reliability was calculated at 0.87 using Cohen's kappa (Carletta, 1996).

[Insert Table 2 about here]

To be able to analyse the pupils' experiences of writing with STT (research question 2), screen recordings and stimulated recall interviews were transcribed and coded using Nvivo 12. Three main categories were identified: (1) benefits, (2) challenges and (3) emotional reactions. The categories emerged through analyses of prominent responses from the stimulated recall interviews and elements considered to influence text production (e.g., interruptions, switches between STT and keyboard or revision strategies) from the screen recordings.

Ethical Considerations

The study follows guidelines provided by the Norwegian Centre for Research Data (NSD) and has received approval from the NSD to collect and store data. All participants gave written and oral consent to take part in the study. As the pupils were 14–15 years old, and their parents also provided consent for their participation. Participation was voluntary, and pseudonyms (Pupils 1–6) are used in place of pupils' names to provide anonymity.

Results

Screen Recording Results

Figure 1 describes how the pupils wrote with STT from lowest to highest number of words produced with STT and the relation to final word count, words typed, words removed and the number of switches between keyboard and STT.

[Insert Figure 1 about here]

All the pupils typed words on the keyboard but produced more words by STT than by typing. The pupils used different approaches to writing with STT; for example, some pupils had fewer switches between keyboard and STT, while others had more frequent transitions. The ratio between words typed and words dictated ranged from 1:5 (Pupil 3) to 1:20 (Pupil 5). There was also variation in fluency and text length between the pupils. Fluency, which was measured in words per minute, ranged from 6.8 (Pupil 6) to 14.5 (Pupil 5) words per minute using STT and from 7.6 (Pupil 6) to 15.3 (Pupil 6) words per minute when typing on a keyboard. Pupil 5 produced the longest text and the highest number of words with STT. Pupil 2, who had dyslexia, produced the second-highest number of words with STT but submitted one of the shortest texts. This is explained by the number of words removed, as Pupil 2 deleted 64% of his text. Except for Pupil 2, there appears to be a tendency for the pupils who produced the most text with STT to submit the longest texts.

[Insert Figure 2 about here]

Accuracy ranged from 70% (Pupils 3 and 6) to 85% (Pupil 1) when comparing what the pupils said to what the STT transcribed. , The accuracy of the final texts ranged from 92% to 97%, except for Pupil 6, who had 75% accuracy. Pupil 6 explained during interviews that he did not revise the accuracy errors on purpose, as he wanted the researchers to see the mistakes the STT technology had made. Figure 1 shows that the pupils were required to make several revisions and, therefore, also switched between keyboard and STT to produce a more accurate text.

An overview of the types of errors recorded is presented in Table 3. The most frequently occurring error (69.1% of categorised errors) was labelled as a transcription error. An error was considered a transcription error if the STT technology produced a similar-sounding word, a misspelled word, a word from another language or if it added or removed a word spoken by the pupil. According to the analyses of screen recordings, all pupils experienced transcription errors, ranging from 23–36 errors for each pupil.

[Insert Table 3 about here]

When some of the pupils produced text with STT without the intention of dictating they were reading their text out loud, thinking out loud or commenting on something while STT was activated. There were occurrences where sounds in the task environment, such as sighing, heavy breathing or other pupils dictating, were picked up by STT and transcribed into text. The most frequent transcription of heavy breathing and sighing was [hm…]. Three pupils experienced that STT picked up and transcribed something that other pupils were saying. Five pupils spoke with the intention to write, yet the STT technology did not respond. At times, this was caused by a technical error that was solved when the pupils turned STT off and on again. On other occasions, pupils attempted to dictate; however, STT had been automatically turned off and, therefore, did not provide any transcriptions. This happened because the software default setting is for dictation to turn off if a pause lasts more than 20 seconds. Six pupils experienced that the STT did not produce any text, even though they spoke and the STT was activated. Pupils 2 and 5 experienced this five times, while the other four pupils experienced it once.

Table 4 presents different subgroups of transcription errors observed and the range and number of pupils who experienced each type of error.

[Insert Table 4 about here]

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The most frequently occurring type of transcription error were semantic errors. These kinds of errors were usually words that sounded somewhat like the word the pupil had pronounced. Sixty-three percent of the transcription errors were semantic errors. STT also produced homophone errors, a word that has a different meaning yet the exact same pronunciation. The most frequently occurring homophone error was the transcription of the Norwegian conjunction 'and' (transcribed 'og'), which is a homophone of the Norwegian infinitive marker (transcribed 'å'). Both 'å' and 'og' are pronounced /ɔ/ when unstressed; thus, accurate spelling presupposes semantic knowledge. This is similar to the homophones 'to' and 'too' in English. The STT software suggested 'å' for 'og' and vice versa. As these errors were not spelling errors but semantic errors, the homophones were not marked by spellcheck. All pupils made two or three homophone errors while writing with STT. Pupils 5 and 6 revised all homophone errors, while the other pupils revised one or two errors, leaving one error in the final text. Another example of transcription errors was the emergence of similar-sounding English words or phrases that were transcribed in English, even though the pupils spoke in Norwegian, and Norwegian was set as dictation language. Four pupils experienced that STT transcribed English or German words. While this happened, on average, 3.25 times per pupil (ranging from zero to five times), most pupils noticed these errors and deleted them during revision.

Interview Results

Perceived Benefits

The main benefits presented by the pupils were that it was exciting to try something new; STT helped with spelling; and it was easier to elaborate when producing text orally. Some pupils said that they experienced text production with STT as faster than typing on a keyboard. One example of spelling assistance was provided by

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Pupil 2, who wanted to write about a documentary on social media: 'So, I was thinking. How do I spell 'documentary'? And then I said it out loud and it just appeared. It [STT] was useful for those difficult words that I don't really know how to spell'.

Several pupils stated that it was easier to argue and elaborate when using dictation. One pupil stated, 'It is easier to explain something when you speak compared to when you have to put it down in writing.' (Pupil 1). Other pupils described similar experiences, emphasising that they were allowed to think aloud and focus on the content that they were trying to convey without having to consider spelling and syntax. Pupil 6 stated that a benefit of writing with STT was that he was able to produce more text in a shorter amount of time. He stated, 'I felt like I was thinking faster. Or… I was thinking at the same speed, but when I wrote with STT, more text appeared'. The pupils described that it was easy to write with STT when the technology was accurate. All six pupils were able to produce a reflective text by speech, even though they reported that they had not been using STT regularly.

Perceived Challenges

The main challenges relate to the use of dialects, transcription errors and disruptions due to revisions. Pupils 4 and 2 stated that they had to alter their pronunciation to a more standard dialect to be successful when dictating. Pupil 4 expressed that it was embarrassing to speak out loud when she had to enunciate each word, while Pupil 2 said, 'I lost focus when I had to say everything clearly and correctly. I noticed that I had to change my dialect to make it able to pick up what I meant. I had to pronounce everything with a posh dialect and that was very distracting'.

Pupil 6 explained that one of the challenges with STT was that he had to plan and speak at the same time. He said, 'When I dictate, the words come straight out of my mouth before I get the chance to think them through'. As he watched himself revise his

text, Pupil 6 explained that he had to delete more text when writing with STT because he did not have the opportunity to formulate sentences and 'test them out' while he was speaking. Others described similar experiences. For example, they had to delete text that they had dictated because they considered it 'too oral'. Two pupils had identified learning disabilities – Pupil 1 had a general learning disability, and Pupil 2 had dyslexia. Comparing Pupils 1 and 2 to the other pupils, the pupils with identified learning disabilities became notably more frustrated during the writing process when they encountered accuracy errors. Pupil 2 stated that he experienced the writing process as less efficient because a lot of time was spent on revision. He explained, 'I got distracted when editing, and then I could not remember what I originally planned to write'.

Emotional Reactions

Some of the pupils stated that it was embarrassing speaking to write because other pupils could listen to what they were saying. Pupil 4 noted that if she had been in a room with only her closest friends, it would not have been embarrassing to use STT. She added that the worst part was that she was sharing her text as it was being produced, not the final version. The pupils reacted differently to the challenges that emerged with STT. Some met the challenges without noticeable reactions, while others were frustrated, and some found it amusing. Pupils 1 and 2 expressed frustration as they experienced transcription errors or technical difficulties. When asked to describe this experience, Pupil 2 explained that it was annoying because he knew he could just type , and he lost focus trying to write by speech. Pupils 1 and 4 giggled when the STT suggested something entirely different from what they had intended to write. For example, the English abbreviation 'omg' (oh my god) was suggested when one of the pupils dictated a phrase with similar sounding phonemes in Norwegian.

Discussion

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The aim of this study was to explore how pupils with low writing achievement approach and experience writing with STT. Findings from screen recordings and stimulated recall interviews showed that pupils with low writing achievement were able to produce reflective texts with STT in Norwegian. However, they experienced both benefits and challenges caused by the technology. The main benefits relate to spelling, allowing the pupils to elaborate arguments orally and the excitement of trying something new. The challenges mainly pertain to disruption due to transcription errors, the need to revise the text by hand and the embarrassment of speaking out loud.

Text Production with STT

The pupils produced texts with STT, and described that they were relieved of some challenges related to spelling when composing with STT. These findings are in line with studies by Ok et al. (2020) and Nordström et al. (2019), who found that STT was especially helpful for pupils who struggled with spelling. However, pupils in the current study could not rely on STT to be 100% accurate and provide correct orthography and syntax in Norwegian. Thus, this study does not entirely support the hypothesis by De La Paz and Graham (1997) stating that STT allows pupils to spend less effort on lower-order skills and enables them to devote more attention to higher-order skills, such as planning content, creating a good structure, and text coherence. It is important to emphasize that this study was conducted with recently integrated STT technology, and transcription errors are likely to be reduced as the technology is further adapted to Norwegian users. When Norwegian language users provide input in different dialects and correct transcription errors, the corpora will grow, and the learning algorithms will be able to produce more accurate output. For example, transcription errors in which STT produces text in languages other than the preferred setting are

likely to disappear as Norwegian text corpora increase. This is likely to cause pupils less disruption and reduce the need for proofreading and editing.

Challenges such as STT being automatically turned off and recognition errors are likely to be reduced as the technology improves. Algorithms underlying STT are already trained to distinguish sounds in the task environment, such as coughing and heavy breathing, from speech input intended for transcription (Yu & Deng, 2016). However, these algorithms must be trained on larger language corpora of specific languages to improve accuracy. As the accuracy of STT improves, the writing experience of pupils with low writing achievement is also likely to improve. Regardless of improved technology, pupils with low writing achievement may still experience a lack of control when writing with STT. The pupils in this study described how STT produced text at a higher pace compared to writing by hand and typing on a keyboard. Research on handwriting and typing shows that compositional fluency correlates with text quality (Troia et al., 2020), yet the experience of higher fluency was not considered a benefit by some of the pupils with low writing achievement in this study. This issue is not likely to be resolved as technology improves.

A challenge with homophone errors is that they are correctly spelled words found in the dictionary; thus, the spell check does not mark them as errors. Some of the pupils did not recognise the homophone errors and did not correct them. Reading, planning, text evaluation and revision are central elements in the writing process and expert writers spend more time editing before considering a text a final product (MacArthur, 2016). Pupils with low writing achievement are also likely to struggle with reading (Wengelin & Arfé, 2017), and even though STT may reduce constraints relating to encoding, as long as the technology is not entirely accurate, pupils still have to decode their texts to check for errors in transcribed text.

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Experiences

The pupils described that it was exciting to try a different approach to writing and easier to elaborate and produce arguments orally compared to when they were typing or writing by hand. However, their emotional reactions of embarrassment, frustration, and amusement epitomise how STT also caused disruption to the writing process. The environmental factors of writing, as described in the WWC model (Graham, 2018), appeared to influence how pupils experienced writing with STT. They had to expose their opinions, and although they were all composing at the same time, they clearly considered their peers' reactions to what they were writing. Thus, providing a safe learning environment is especially important when pupils in lower secondary education produce texts with STT. It should be noted that writing in educational contexts may be distinctive from writing in other contexts. As the pupils stated that it would have been less embarrassing to produce text with STT with only close friends, it is recommended to introduce and practice using the technology during low-stakes activities in a safe learning environment where the pupils feel secure speaking out loud and are less concerned with producing texts of very high quality.

The two pupils with identified learning disabilities expressed frustration when they encountered accuracy errors. The pupil with dyslexia stated that it was frustrating to use STT because he could just type what he wanted to write instead. However, according to the measures of the pupil's spelling ability (see Table 1), he was also likely to make spelling mistakes when typing. The fact that some pupils experience more frustration when writing with STT is supported by previous research (e.g., Ok et al., 2021). Personality traits and emotions are central elements in writing, according to the WWC model (Graham, 2018). Thus, it is worth noting that even as STT technology improves, pupils with low self-efficacy towards writing are likely to have less patience

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and perseverance when testing out new writing approaches. They may also have more to lose if STT does not provide sufficient assistance compared to their peers, who, to a larger degree, master writing by hand or typing. Thus, as is important with all assistive technologies, teaching professionals should consider and evaluate individual benefits and constraints (Edyburn, 2006) when introducing pupils to STT.

Implications for Practice and Future Research

For pupils who have the prerequisites to understand how STT works, it is useful to explain in simple terms why the technology will benefit from clear and continuous dictation.

Continuous dictation is more likely to improve than word-to-word dictation, as speech input algorithms perform better when they receive more input and can learn from the context (Yu & Deng, 2016). Consequently, when a STT writer pauses between words, the software is less able to use the surrounding words as contextual indicators and prediction accuracy is reduced. Pupils should therefore be advised to dictate continuously, even as STT technology improves.

Furthermore, as algorithms learn from feedback, pupils can be encouraged to correct transcription errors to improve the technology. STT alone cannot solve every challenge related to text production for pupils with low writing achievement. Even if accuracy improves and STT becomes an efficient transcription aid, it is equally important to provide pupils with writing strategies and capabilities to approach other aspects of writing, such as ideation, planning, reviewing, and revising while using STT. It is also important to provide instruction on how to write using STT. Compared to handwriting, to which there is devoted a lot of time and practice in elementary education (Fancher et al., 2018), research on typing shows that few teachers provide keyboarding instructions (Poole & Preciado 2016) because pupils are considered to acquire typing without formal

instruction (Grabowski 2008). This study indicates that it is important to provide instructions on how to utilize STT as pupils with low writing achievement experience difficulties when approaching this writing modality.

As schools were closed down to prevent the spread of the COVID-19 virus, the pupils had only a few weeks to practice writing with STT. This was not enough time to master a new writing approach. It should be noted that STT is likely to be more accurate in widespread languages such as English, French, Spanish or Chinese (McCrocklin et al., 2019; Yu & Deng, 2016). Thus, being allowed to use STT and keyboard during writing exercises in foreign language learning, may be beneficial for pupils with low writing achievement. Further research on STT should include longitudinal studies to explore the benefits and challenges of using STT in Norwegian and foreign languages over time for pupils with low writing achievement.

Limitations of the Study

The pupils in this study were introduced to STT approximately four hours per week for a 10-week period. However, this study was conducted eight months after this introduction period, as schools were closed due to the COVID-19 pandemic. During the eight months between the introduction period and the stimulated recall writing session, the pupils reported that they had not been using STT on a regular basis. Some of the challenges reported in the results, such as STT turning off automatically, may be explained by a lack of practice and familiarity with the technology. The software provided had only been available in Norwegian in Microsoft Office for approximately one year at the time of data collection. The high number and variety of recognition errors may be caused by software building on a relatively small language corpus.

When analysing the stimulated recall interviews, it became apparent that the pupils, to a larger degree, described the content of their texts and challenges with the

technology rather than their experience of writing with a different modality. Future research on adolescents with low writing achievement should consider that the stimulated recall procedure sets high demands on the informants' metalinguistic knowledge and ability to reflect on their own writing process. It should also be noted that this study contains a small sample of six pupils using rural dialects to produce a reflective text with STT in the southern part of Norway. The sample size and design of the study do not provide an opportunity to generalise findings to larger populations of pupils with low writing achievement. Yet, some of the findings may be applicable to pupils using STT in other Nordic languages as well, as the STT technology is likely to be as inaccurate in other smaller languages compared to widespread languages such as English or Chinese.

Concluding Remarks

This study indicates that at STT is not yet the ideal writing technology for pupils in Norwegian lower secondary education with low writing achievement. The pupils experienced transcription errors and technological inaccuracies, while elements that may have been considered a benefit of using STT also caused the participants some distress. For example, the process of speaking instead of typing – which is faster and was expected to lead to more fluent production—was not considered a benefit by all. However, there are some recognizable benefits, and STT may become an efficient writing modality as Norwegian speech recognition technology develops. The findings underline the importance of providing sufficient instruction and a safe learning environment if pupils with low writing achievement are to exploit the technology's potential in an educational context.

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Table 1

Demographic Information and Results on Reading and Writing Tests

Pupil	Gender	National Reading Test (level)	Spelling test (percentile)	Age (y;m)	Grade	Identified learning disability
1	F	1	30th	15;5	10	General learning disability
2	M	2	5th	14;1	9	Dyslexia
3	F	2	30th	14;11	10	Under assessment for dyslexia
4	F	2	30th	14;3	9	Under assessment for dyslexia
5	M	3	20th	15;7	10	No
6	M	2	30th	15;8	10	No

Table 2

Operationalization of Measures of Text Production and Interrater Reliability

Measures	Operationalization	Inter-rater reliability (Cohen's kappa)
Words produced with STT	Number of words transcribed by the STT technology, including words that were deleted	0.92
Total number of words produced	Number of words produced, either with STT or keyboard, including words that were deleted	0.86
Typing-STT ratio	Number of words typed on a keyboard divided by the number of words produced with STT, including words that were deleted	0.70
Words produced with STT per minute	Number of words produced with STT divided by 15 (minutes)	0.88
Total words per minute	Total amount of words produced divided by 15 (minutes)	0.86
Words removed	Number of words removed. If the pupil removed one or several letters but not the entire word, it was still counted as one word removed.	0.76
Switches between STT and keyboard	Number of times the pupil switches from keyboard to STT or from STT to keyboard	0.91
Accuracy in text produced with STT	Words produced with STT minus number of words incorrectly transcribed by the STT divided by number of words produced with STT	0.89
Final accuracy	Final word count minus number of errors in the submitted text divided by final word count	0.94
Final word count	Number of words included in the submitted version of the text	1.0

Table 3

Number and Percent of Errors Observed and the Range and Number of Pupils Who Experienced Each Type of Error

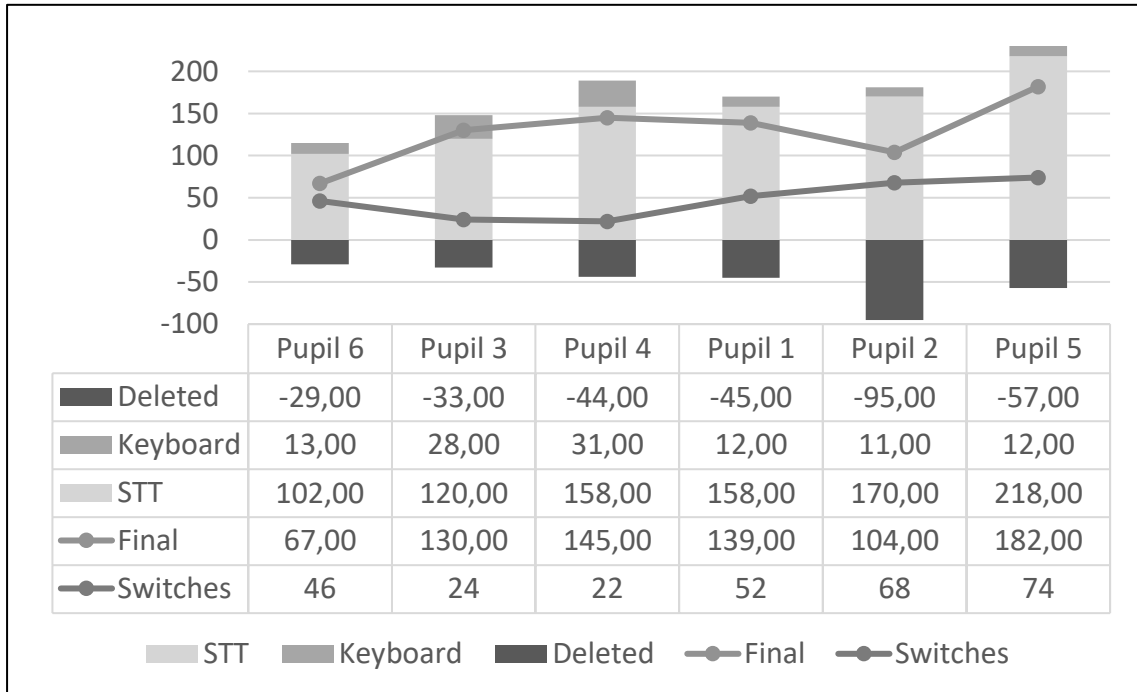|	Number of times error observed	Percent of total errors (n = 259)	Number of pupils (n = 6)	Range across pupils (min-max)
Transcription errors	179	69.1%	6	23–36
Produces text without intending to dictate	28	10.8%	4	0–12
Erroneous capitalization	19	7.3%	6	1–9
Speech not registered by STT	13	5.0%	5	0–5
Dictates while STT is switched off	11	4.2%	5	0–5
STT registers speech from other pupils	9	3.5%	3	0–4

Table 4

Number and Percent of Transcription Errors Observed and the Range and Number

of Pupils Who Experienced Each Type of Error

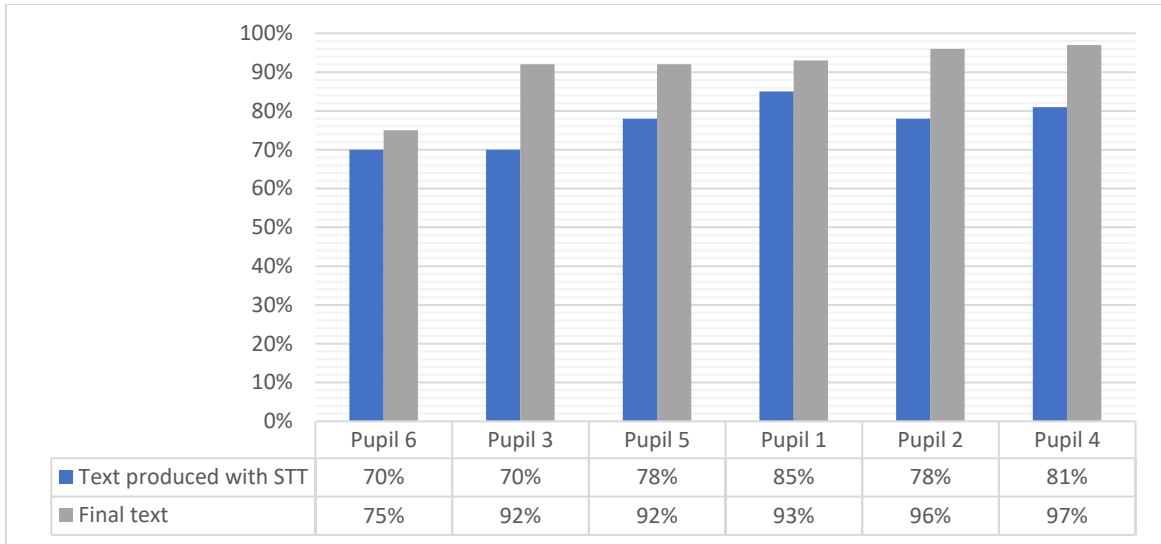|	Number of times error observed	Percent of total transcription errors (n = 179)	Number of pupils (n = 6)	Range across pupils (min-max)
Semantic errors	114	63.1%	6	14–23
Homophone errors	15	8.9%	6	2–3
STT adds words that were not dictated	24	13.4%	6	3–6
STT suggests text in another language	11	6.1%	3	0–5
Spelling errors	9	5.0%	4	0–3
STT does not transcribe words that were dictated	6	3.3%	3	0–3

Figure 1

Words Produced with STT from Lowest to Highest and their Relation to Final Word

Count, Words Typed, Words Removed and Switches between Keyboard and STT

	Pupil 6	Pupil 3	Pupil 4	Pupil 1	Pupil 2	Pupil 5
Deleted	-29,00	-33,00	-44,00	-45,00	-95,00	-57,00
Keyboard	13,00	28,00	31,00	12,00	11,00	12,00
STT	102,00	120,00	158,00	158,00	170,00	218,00
Final	67,00	130,00	145,00	139,00	104,00	182,00
Switches	46	24	22	52	68	74

Figure 2

Accuracy of Text Produced with STT and Accuracy in Final Text, Sorted from Least to

Most Accurate Final Text

	Pupil 6	Pupil 3	Pupil 5	Pupil 1	Pupil 2	Pupil 4
■ Text produced with STT	70%	70%	78%	85%	78%	81%
■ Final text	75%	92%	92%	93%	96%	97%

Appendix 4. *Co-Author Declaration*

UiA Faculty of Humanities and Education

Co-author declaration

For dissertation that includes articles with more than one author, the following applies (10.1 in Regulations for the degree of PhD at the University of Agder):

- *The PhD student should provide a brief description of his/her input into each component. The description is to be attached to the dissertation.*
- *This description is also used as a declaration of associate authorship and should be signed by the PhD student, the principal supervisor (where he/she is an associate author), and the other two most central authors.*

Article title: A Scoping Review on the use of Speech-to-Text Technology for Adolescents with Learning Difficulties in Secondary Education
Place of publication: Disability and Rehabilitation: Assistive Technology
Lead author: Marianne Engen Matre
PhD student: Marianne Engen Matre
Co-author(s), if any: David Lansing Cameron
PhD student's contribution (please describe (text) in addition to estimate percent (%)): The PhD candidate conducted approximately 80 % of the total workload for the article entitled "A Scoping Review on the use of Speech-to-Text Technology for Adolescents with Learning Difficulties in Secondary Education". This consisted of: • Exploring existing research • Discussing and determining the article's scope and aim • Exploring research databases • Creating a search string • Conducting searches for peer-reviewed articles • Searching and screening grey literature • Reading abstracts and screen for eligible peer-reviewed articles • Defining inclusion and exclusion criteria • Creating tables and flow-charts • Reading full-text articles • Including relevant studies • Calculating inter-rater reliability • Writing feedback and make alterations as part of the review process • Writing most of the drafts and the final version of the article

9.5.23 *Marianne Engen Matre*
_____
Date and the PhD student's signature

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Date and the lead author's signature

9.5.23
_____
Date and a central author's signature

_____
Date and the principal supervisor's signature, if required

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Appendix 5. *Application NSD (Norwegian Center for Research Data)*

NSD NORSK SENTER FOR FORSKNINGSDATA

NSD sin vurdering

Prosjekttittel

STIL (Speech Technology for Improved Literacy)

Referansenummer

199500

Registrert

02.07.2019 av Marianne Engen Matre - marianne.e.matre@uia.no

Behandlingsansvarlig institusjon

Universitetet i Agder / Fakultet for humaniora og pedagogikk / Institutt for pedagogikk

Prosjektansvarlig (vitenskapelig ansatt/veileder eller stipendiat)

Marianne Engen Matre, marianne.e.matre@uia.no,

Felles behandlingsansvarlige institusjoner

Statped / Forskning og utvikling
Norges teknisk-naturvitenskapelige universitet NTNU / Fakultet for samfunns- og utdanningsvitenskap (SU) / Institutt for lærerutdanning
Høgskolen i Østfold / Avdeling for lærerutdanning

Type prosjekt

Forskerprosjekt

Prosjektperiode

01.08.2019 - 31.12.2022

Status

17.07.2019 - Vurdert

Vurdering (1)

17.07.2019 - Vurdert

Det er vår vurdering at behandlingen vil være i samsvar med personvernlovgivningen, så fremt den gjennomføres i tråd med det som er dokumentert i meldeskjemaet den 17.07.2019 med vedlegg, samt i meldingsdialogen mellom innmelder og NSD. Behandlingen kan starte.

MELD VESENTLIGE ENDRINGER
Dersom det skjer vesentlige endringer i behandlingen av personopplysninger, kan det være nødvendig å melde dette til NSD ved å oppdatere meldeskjemaet. Før du melder inn en endring, oppfordrer vi deg til å lese om hvilke type endringer det er nødvendig å melde:

https://nsd.no/personvernombud/meld_prosjekt/meld_endringer.html

Du må vente på svar fra NSD før endringen gjennomføres.

TYPE OPPLYSNINGER OG VARIGHET
Prosjektet vil behandle særlige kategorier av personopplysninger om helse og alminnelige personopplysninger frem til 31.12.2022.

LOVLIG GRUNNLAG
Prosjektet vil innhente samtykke fra de registrerte til behandlingen av personopplysninger. Vår vurdering er at prosjektet legger opp til et samtykke i samsvar med kravene i art. 4 nr. 11 og art. 7, ved at det er en frivillig, spesifikk, informert og utvetydig bekreftelse, som kan dokumenteres, og som den registrerte kan trekke tilbake.

Lovlig grunnlag for behandlingen vil dermed være den registrertes uttrykkelige samtykke, jf. personvernforordningen art. 6 nr. 1 a), jf. art. 9 nr. 2 bokstav a, jf. personopplysningsloven § 10, jf. § 9 (2).

PERSONVERNPRINSIPPER
NSD vurderer at den planlagte behandlingen av personopplysninger vil følge prinsippene i personvernforordningen om:

- lovlighet, rettferdighet og åpenhet (art. 5.1 a), ved at de registrerte får tilfredsstillende informasjon om og samtykker til behandlingen
- formålsbegrensning (art. 5.1 b), ved at personopplysninger samles inn for spesifikke, uttrykkelig angitte og berettigede formål, og ikke viderebehandles til nye uforenlige formål
- dataminimering (art. 5.1 c), ved at det kun behandles opplysninger som er adekvate, relevante og nødvendige for formålet med prosjektet
- lagringsbegrensning (art. 5.1 e), ved at personopplysningene ikke lagres lengre enn nødvendig for å oppfylle formålet

DE REGISTRERTES RETTIGHETER
Så lenge de registrerte kan identifiseres i datamaterialet vil de ha følgende rettigheter: åpenhet (art. 12), informasjon (art. 13), innsyn (art. 15), retting (art. 16), sletting (art. 17), begrensning (art. 18), underretning (art. 19), dataportabilitet (art. 20).

NSD vurderer at informasjonen som de registrerte vil motta oppfyller lovens krav til form og innhold, jf. art. 12.1 og art. 13.

Vi minner om at hvis en registrert tar kontakt om sine rettigheter, har behandlingsansvarlig institusjon plikt til å svare innen en måned.

FØLG DIN INSTITUSJONS RETNINGSLINJER
NSD legger til grunn at behandlingen oppfyller kravene i personvernforordningen om riktighet (art. 5.1 d), integritet og konfidensialitet (art. 5.1. f) og sikkerhet (art. 32).

Statped, NTNU og Høgskolen i Østfold er felles behandlingsansvarlige institusjoner sammen med UiA. NSD legger til grunn at behandlingen oppfyller kravene til felles behandlingsansvar, jf. personvernforordningen art. 26.

TSD 2.0 er databehandler i prosjektet. NSD legger til grunn at behandlingen oppfyller kravene til bruk av

databehandler, jf. art 28 og 29.

For å forsikre dere om at kravene oppfylles, må dere følge interne retningslinjer og eventuelt rådføre dere med behandlingsansvarlig institusjon.

OPPFØLGING AV PROSJEKTET
NSD vil følge opp underveis (hvert annet år) og ved planlagt avslutning for å avklare om behandlingen av personopplysningene er avsluttet/pågår i tråd med den behandlingen som er dokumentert.

Lykke til med prosjektet!

Kontaktperson hos NSD: Karin Lillevold
Tlf. Personverntjenester: 55 58 21 17 (tast 1)