Speech production and literacy in students with intellectual disabilities and communication difficulties

Department of Health and Rehabilitation

Institute of Neuroscience and Physiology

Sahlgrenska Academy, University of Gothenburg

UNIVERSITY OF GOTHENBURG

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SVANENMÄRKET

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3041 0234

To my loving family, you are everything that matters.

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Jenny Samuelsson

Department of Health and Rehabilitation, Institute of Neuroscience and Physiology
Sahlgrenska Academy, University of Gothenburg
Gothenburg, Sweden

ABSTRACT

Many individuals with intellectual disabilities have difficulties with spoken communication and literacy learning leading to vulnerability. It has been suggested that interventions to promote reading in this group not only influence literacy acquisition but may also have an impact on speech and language development. The overall aim of this thesis was to examine the associations between speech production and literacy skills in students with intellectual disabilities and communication difficulties and to investigate the potential impact of a literacy intervention on speech production from the perspectives of both teachers and students with intellectual disabilities and communication difficulties themselves and by comparing test data before and after intervention.

A literacy intervention was conducted with 137 students, aged 7-21. All students had intellectual disabilities, communication difficulties, and were unable to phonetically decode words or comprehend more than 20 words. The literacy intervention compared three different teaching approaches using digital applications, (phonics, comprehension-based and a combination of both approaches) with teaching-as-usual. Study I *Associations* analysed test data before intervention and found that early literacy skills accounted for 26% of the variance in speech sound production. Study II *Students' views* presented the students' positive and negative views on speech and reading activities using

the visual framework Talking Mats and found that these ratings correlated with test results. Study III *Teachers' views* presented thematically analysed interviews with teachers in the combined intervention group showing that the teachers reported improvements in both literacy skills and communication for some of the students and emphasized the importance of providing structured and focused literacy instruction for these students. Study IV *Intervention* statistically investigated the effect of literacy intervention on speech sound production indicating that literacy intervention may have secondary effects. In conclusion, this thesis shows that there is an association between speech sound production and early literacy skills and suggests that literacy intervention may have secondary effects on speech production in students with ID and communication difficulties, although future research is needed to confirm this.

Keywords: Intellectual disability, augmentative and alternative communication, speech sound production, early literacy skills, literacy, literacy intervention.

SAMMANFATTNING PÅ SVENSKA

Många barn och vuxna med intellektuell funktionsnedsättning (IF) har svårigheter med kommunikation och är i behov av alternativ och kompletterande kommunikation. Dessa individer har ofta omfattande svårigheter med läs- och skrivförmåga. En viktig anledning till att stimulera skriftspråksutvecklingen för denna grupp av elever, förutom den primära aspekten att förvärva läs- och skrivförmåga, är den möjliga positiva inverkan på tal- och språkutveckling som ofta beskrivs i klinisk och pedagogisk praktik.

Det övergripande syftet med denna avhandling var att undersöka sambanden mellan talproduktion och läsfärdigheter och att undersöka den potentiella påverkan av digital läsintervention på talproduktionen hos elever med IF och kommunikationssvårigheter. Detta undersöktes både utifrån lärarnas och elevernas egna perspektiv samt baserat på talproduktion före och efter läsinterventionen.

Avhandlingens studier utfördes inom ramen för det större forskningsprojektet KomLoss som inkluderade 137 elever i anpassad grundskola/gymnasieskola i åldrarna 7–21 år. Eleverna delades in i fyra olika interventionsgrupper; ljudningsbaserad undervisning, förståelsebaserad undervisning, en kombination av båda undervisningsstrategierna samt en grupp som fick undervisning som vanligt. Läsinterventionen utfördes i 12 veckor. Applikationerna (apparna) som användes i läsinterventionen var Animega-interaktiv språklek för förståelsebaserad undervisning och Accessible Literacy Learning för ljudningsbaserad undervisning.

Studie I *Samband*, visade att tidiga läsförmågor som fonologisk medvetenhet och bokstavs-ljudkännedom förklarade 26% av variansen i talet hos 116 elever med IF och kommunikationssvårigheter. Resultatet visade också att denna association mellan tidiga läsförmågor och kvalitet i talproduktion inte kunde förklaras av ålders- eller begåvningsfaktorer.

Studie II *Elevernas uppfattning*, undersökte elevernas åsikter (n=111) om tal- och läsaktiviteter med hjälp av den bildbaserade samtalsmetoden Samtalsmatta. Eleverna uppskattade mer att prata enskilt en till en och i telefon i jämförelse med att prata i grupp. Skattningen av läsaktiviteter blev även mer negativ ju mer avancerade läsaktiviteterna var. Skattningarna av tal- och läsaktiviteter kvantifierades och befanns vara signifikant associerade med testresultat på motsvarande förmågor som talproduktion samt ordläsning. En

viktig klinisk implikation är att det är möjligt att tillgodose dessa elevers rätt att uttrycka sina egna åsikter givet att de får rätt kommunikativt stöd.

Studie III *Lärarnas uppfattning*, presenterar lärarnas åsikter (n=8) i tematiskt analyserade intervjuer från den grupp som hade kombinerad läsundervisning med båda applikationerna. Studien visade att lärarna uppfattade förbättringar både vad gäller läsfärdigheter och kommunikation för vissa elever efter interventionen. Analysen pekade på vikten av att tillhandahålla strukturerad och fokuserad läsinstruktion för dessa elever utöver den värdefulla interaktionen mellan lärare och elev.

Studie IV *Intervention*, inkluderade 121 elever med IF och kommunikationssvårigheter och resultaten indikerade att läsinterventionen, oavsett undervisningsstrategi (ljudningsbaserad, förståelsebaserad eller en kombination av båda), kan ha sekundära effekter på produktionen av språkljud. Dock visade sensitivitetsanalyser att resultaten var osäkra och behöver därför följas upp i framtida forskning.

För framtida forskning är det viktigt att fortsätta undersöka tal i förhållande till läsförmåga för elever med IF och kommunikationssvårigheter. Detta inkluderar att uppmärksamma modererande och medierande faktorer såsom ordförråd, arbetsminne, fonologisk medvetenhet, oral sensation och perception, uppmärksamhet, oralmotorisk funktion, elev-lärarinteraktion och läs- och språkexponering. Att få mer kunskap om dessa faktorer kan ge ytterligare perspektiv på tal och de effekter olika typer av läsintervention kan medföra.

Att se bortom svårigheter och erkänna möjligheter är viktigt för att skapa en inkluderande forskningspraxis. Särskilt bör framtida forskning lägga stor tonvikt på att involvera deltagarna och undersöka möjligheterna att samla in deras åsikter, speciellt när deltagarna har en IF och kommunikationssvårigheter som extra utmaning.

LIST OF PAPERS

This thesis is based on the following studies, which are referred to in the text by their Roman numerals and an abbreviated title.

I. Samuelsson, J., Åsberg Johnels, J., Thunberg, G., Palmqvist, L., Heimann, M., Reichenberg, M., Holmer, E. (2023). The relationship between early literacy skills and speech-sound production in students with intellectual disability and communication difficulties: a cross-sectional study. *International Journal of Developmental Disabilities*, 1-11.

II. Samuelsson, J., Holmer, E., Johnels, J. Å., Palmqvist, L., Heimann, M., Reichenberg, M., Thunberg, G. (2023). My point of view: Students with intellectual and communicative disabilities express their views on speech and reading using Talking Mats. *British Journal of Learning Disabilities*, 1, 1-13.

III. Samuelsson, J., Johnels, J. Å., Holmer, E., Palmqvist, L., Heimann, M., Reichenberg, M., Lundälv, M., Thunberg, G. 'To have a plan': Teachers' perceptions of working with a literacy instruction combining phonics and comprehension applications for students with intellectual disability and communication difficulties. Submitted for publication.

IV. Samuelsson, J., Thunberg, G., Johnels, J. Å., Palmqvist, L., Heimann, M., Reichenberg, M., Lundälv, M., Holmer, E. The potential impact of literacy intervention on speech sound production in students with intellectual disability and communication difficulties. Submitted for publication.

CONTENTS

ABBREVIATIONS

AAC	Augmentative and Alternative Communication
ADHD	Attention-Deficit/Hyperactivity Disorder
ALL	Accessible Literacy Learning
Animega-is	Animega-interactive sentences (interaktiv språklek)
ASD	Autism Spectrum Disorder
DiLL	Digital Literacy Learning for Students with Intellectual Disabilities
DSM-V	Diagnostic and Statistical Manual for of Mental Disorders Fifth Edition
FUB	The Swedish National Association for People with Intellectual Disability
ICD-10	International Statistical Classification of Diseases and Related Health Problems, Tenth Edition
ID	Intellectual Disabilities
PPC	Percent Phonemes Correct

THESIS AT A GLANCE

Paper	Aims	Methods	Results	Conclusions
I Associations	To investigate the associations between early literacy skills and speech sound production in students with ID and communication difficulties.	Cross-sectional quantitative study including test data before intervention from speech sound production, phonological awareness, and letter-sound knowledge in a regression analysis. (n=116)	Early literacy skills were moderately and significantly correlated with speech sound production. Phonological awareness and letter-sound knowledge explained 26% of the variance in speech sound production.	The findings indicated a connection between phonological awareness, letter-sound knowledge, and speech sound production.
II Students' views	To investigate the perceptions of speech and reading activities by students with ID and communication difficulties and how consistent these are with their test results on speech production and reading ability.	Interviews with students with ID and communication difficulties using Talking Mats. The views were quantified, and associations with the test results for speech sound production and word reading were carried out. (n=111)	There was a positive correlation between the scored views on speech and speech production, as well as a positive relationship between the scored views on reading activities and reading ability.	The students were able to express their views on reading and communication with Talking Mats. Their views were also consistent with their results on tests that were used.
III Teachers' views	To explore the teachers' perception of the students' development regarding reading ability, speech, and communication during a combined digital literacy intervention including phonics and comprehension-based instructions.	Semi-structured dyad interviews with participating teachers. The data were analysed using thematic analysis. (n=8)	Four themes were identified: The engaging effect of participating in the research project; Digital tools as scaffolding for learning; The impact of a supportive teaching environment and Student development.	The teachers' role as a motivator and provider of adapted material and structure are important features for literacy development and communication. Teachers noted improvements for many students in both literacy and communication skills on different levels.
IV Intervention	To investigate if digital literacy intervention affects speech sound production in students with ID and communication difficulties.	Quasi-experimental design. Students participated in a literacy intervention. Speech assessment with percentage phoneme correct was performed before and after the literacy intervention period. (n=121)	The findings indicate a possible positive effect of literacy intervention on speech sound production. However, the sensitivity analyses did not show the same positive effect.	Enhancing literacy skills through phonics and comprehension-based approaches, may also result in positive improvements in the speech abilities of students with ID and communication difficulties.

INTRODUCTION

The ability to communicate is important for quality of life, participation, and well-being. Having the opportunity to develop one's communicative ability, including written communication, is a basic need and a right for everyone in today's society (United Nations Conventions on the Rights of Persons with Disabilities, 2006). For individuals with intellectual disabilities (ID) and communication difficulties, using speech as a mean of communication can be a challenge. Many need augmentative and alternative communication (AAC) to be able to communicate with others. If speech can be improved, it provides faster ways to communicate and interact.

In a recently published report from FUB (The Swedish National Association for People with Intellectual Disability, 2023), 408 parents to children between 7-21 were asked about their thoughts on their child's education. One-third of the parents reported that their children did not receive sufficient support to develop their language and communication skills, and that the school did not adequately support the child in developing their reading and writing abilities. This points to the challenge of instructing this group of children, especially those with communication difficulties in need of AAC. Providing teachers with knowledge and adapted research-based material for students with ID and communication difficulties are important steps in enhancing the opportunity for these students to learn how to read and write.

This thesis involved students attending the Swedish school for students with ID and their teachers. The participating students in this thesis have different degrees of difficulties ranging from mild to severe ID, and these difficulties have a pronounced impact on their communicative abilities to the extent that they are in need of AAC in their daily lives. This group is sometimes referred to in literature as "persons with complex communication needs". Since this term is difficult to interpret and use in Swedish, and lacks a definition and operationalisation, the term "students with ID and communication difficulties" is employed in this thesis to characterize the group. The overall aim of this thesis was to examine the associations between speech production and literacy skills in students with ID and communication difficulties and to investigate the potential impact of a literacy intervention on speech production, from the perspectives of both teachers and students with ID and communication difficulties themselves and by comparing test data before and after intervention.

INTELLECTUAL DISABILITY

Intellectual Disability (ID) is a neurodevelopmental disorder with a combination of limitations in intellectual and adaptive functioning. According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) by the American Psychiatric Association (APA), in 2013, the diagnosis of ID includes difficulties in planning, problem-solving, abstract thinking, and learning. Additionally, there should be deficits in adaptive functioning, indicating difficulties in independently performing tasks comparable to others of the same age. Support in communication, social interaction, and everyday activities is necessary for independent living and should be required in various environments, including home, school, work, and community. Deficits in intellectual and adaptive functioning should manifest during childhood.

According to the diagnostic manual of International Classification of Disabilities, Tenth Edition (ICD-10), the cutoff for intellectual functioning is typically indicated by an IQ score from a standardized test of 70 or below (World Health Organization (WHO), 2007). The diagnosis of ID is categorized into four severity levels: mild (IQ 70-50), moderate (IQ 35-50), severe (IQ 20-35), and profound (IQ < 20). Individuals with ID require varying degrees of support in their daily lives based on the severity level (Bridges et al., 2020).

ID has no single cause. It can be associated with genetic disorders such as Down syndrome (Bull, 2020) and Fragile X (Theodore et al., 2023), but there are also other possible causes, such as metabolic diseases, trauma, complications at birth resulting in brain damage or unknown origins (Patel et al., 2020). Additionally, other neurodevelopmental disorders, such as autism spectrum disorder (ASD) and attention-deficit/hyperactivity disorder (ADHD) frequently co-occur with ID (Rydzewska et al., 2019; Tonnsen et al., 2016). Epilepsy and visual and hearing impairments are frequently observed to occur concurrently in individuals with ID (Liaoi et al., 2021).

Evaluating intellectual and adaptive functioning using standardized tests can be challenging. In cases where standardized tests are not a reliable option, a diagnosis of ID and its severity is determined through clinical evaluation findings (APA 2013; WHO 2007). In Sweden, ICD-10 is used to diagnose ID, and for a diagnosis, thorough evaluation of the child needs to be performed by a physician and/or a psychologist.

COMMUNICATION, SPEECH, AND LITERACY

Communication is a prerequisite for learning and participation Human communication encompasses a varied set of nonverbal and verbal means of expressing information and emotions. Language involves understanding and using words and sentences to share ideas and information. This can happen in different ways, such as speaking, reading, writing, through pictures, or by using sign language (Linell, 1982; Owens, 2008). When an individual has communication difficulties, the ability to "receive, send, process and comprehend concepts or verbal, nonverbal and graphic symbols" is impaired (American Speech-Language-Hearing Association, 1993).

One of the theoretical perspectives in this thesis is the sociocultural perspective on development according to Vygotsky, which states that learning and development are intertwined with social experiences and cultural practices, and that individuals acquire knowledge and skills through interactions with others in their social environment (Vygotskij, 1978). Vygotsky refers to the difference between what the student can do independently and what they can achieve with guidance from others such as their teacher in a scaffolding teaching environment (Vygotskij, 1978; Wood et al., 1976).

Further, by also seeing that social interaction and collaboration are important in the acquisition of language, perhaps even more so for students with ID, Tomasello's sociopragmatic usage-based theory (2003) is relevant as an overarching perspective in this thesis. Students who attend schools for students with ID often depend on their teacher or other staff member to interact and support them in their proximal process. Tomasello states that children learn language by watching, listening, imitating, and especially by interacting with adults and peers around them. This usage-based theory of language acquisition can be summarized by two key principles: *meaning is use* and *structure emerges from use*. The first principle emphasizes the functional or semantic aspect of language communication. Language is a tool for communication and is fundamentally tied to its functional purpose. Children learn language by observing and participating in meaningful exchanges with others, where words and expressions are used to convey intentions, share information, and accomplish various social goals. The second principle focuses on the development of grammatical structures and linguistic patterns. According to Tomasello (2003), the structural aspects of language, including grammar and syntax, emerge from repeated instances of language use. Further, the usage-based theory highlights the importance of social interaction. In the context of

this thesis, the interaction can be seen between the student and their teacher during the lessons. This interaction involves meaningful content, addressing both comprehension and form-related aspects of language.

COMMUNICATION IN INDIVIDUALS WITH ID

Communication in the different levels of ID is a spectrum that ranges from delayed speech and language development to complete dependence on others to notice and interpret the person's individual signals. The level of ID is a strong predictor of communication difficulties (Memisevic & Hadzic, 2013; Smith et al., 2020). At the same time, it is important to note that there is considerable variability among individuals within each level of ID. The level of support needed for communication can also be influenced by factors such as the presence of associated conditions, educational opportunities, and individual strengths and preferences. Deficits in cognitive functioning may present challenges in learning skills such as reading, writing and arithmetic (APA 2013).

Individuals with mild ID often have communication skills closer to those of the general population. Vocabulary can be affected, but it is not necessarily noticeable in everyday conversations. While basic communication skills may be relatively strong, individuals with mild ID may still face difficulties with more advanced language skills, such as the comprehension of abstract or nuanced language (APA 2013).

For individuals with moderate ID, speech and language development is delayed, and vocabulary and syntax abilities are typically limited (APA 2013). It may also be difficult to comprehend abstract concepts and complex language. Communicative support is often needed for the individual to function in everyday life and AAC is something that often is needed for both expression and comprehension (Beukelman & Light, 2020).

Communication for individuals with severe to profound ID is often characterized by limited or no speech and often depends on gestures, facial expressions, and other body communication. Individuals have difficulties understanding language and communication is often focused on the "here and now" (APA 2013). Individualised AAC is recommended to meet the specific communication needs (Beukelman & Light, 2020). Communication often involves a high degree of dependence on caregivers or support personnel who are familiar with the individual's unique expressions and needs (Flink et al., 2023; Griffiths & Smith, 2016).

SPEECH DIFFICULTIES IN INDIVIDUALS WITH ID

Speech sound production means articulating and generating sounds to produce speech, which requires many functions, such as cognition, as well as linguistic, motor and anatomical aspects (Linell, 1982). In this thesis, speech sound production has been examined by analysing the participants' phoneme production, regardless of aetiology. Phonemes are the smallest units of sound in a language that can distinguish meaning and differentiate words from one another. Allophones are the different variations of a phoneme that occur in different phonetic contexts but do not change the meaning of the word (Linell, 1982). By the age of six, Swedish children have normally established all phonemes in the language (Blumenthal & Lundeborg Hammarström, 2014).

The linguistic perspective describes difficulties in different language domains including phonology (sound patterns), syntax (sentence structure), semantics (meaning of words and sentences), and pragmatics (use of language in context) (Owens, 2008). It focuses on speech production, and uses the terms *phonetic* and *phonological*. The term phonetic refers on how children learn to produce correct sounds by using the parts of the speech apparatus. Speech errors are common distortions such as lisping of /s/ sounds or the simplification of /r/ to /j/. If these difficulties persist beyond the age of nine, they are often called persistent speech errors (Bowen, 2015). Phonological difficulties are not only about having difficulty in executing speech movements, but also about having difficulties regarding the sound system: how the sounds are used to construct meaning, combined, and what rules exist (Bowen, 2015). An example is a child who is able to pronounce a specific sound in isolation but who has difficulty using the same sound in words.

Speech difficulties can have various causes, and the umbrella term speech sound disorder refers to both known and unknown aetiology (International Expert Panel on Multilingual Children's Speech, 2012). Speech sound disorders can include any combination of difficulties with functional impairments (phonology and articulation), as well as developmental or acquired speech difficulties (structural abnormalities, sensory/perceptual disorders or motor/neurological causes). The latter cause includes childhood apraxia of speech, meaning challenges in voluntary speech production, and childhood dysarthria, meaning difficulties in producing precise and clear speech (APA, 2013; WHO, 2007). Both childhood dysarthria and childhood apraxia of speech can co-occur, and in research and in the clinical setting, distinguishing between these conditions can be a challenge (Iuzzini-Seigel et

al., 2022; Shriberg et al., 2019). Speech motor delay is also a delay in speech development in terms of precision and articulation, but it is not consistent with childhood apraxia of speech and childhood dysarthria (Shriberg et al., 2019).

When looking into the prevalence of speech difficulties in individuals with ID, the research is sparse, but Shriberg et al. (2019) have attempted to estimate this for persons with complex neurodevelopmental disorders (including idiopathic ID, Down syndrome and ASD). Out of 246 participants (average age 13.3 years), a total of 47.7 % met the criteria for one of the following classifications: speech motor delay (25.1%), childhood dysarthria (13.3%), childhood apraxia of speech (4.3%), and a combination of the two (4.9%). In the total sample in Shriberg et al. (2019), the prevalence of phonological difficulties was 40%, ranging from 16.7% for ASD to 93.3% for Down syndrome. This suggests underlying cognitive challenges with language in combination with oral motor difficulties for individuals with ID. Individuals with ID have a very heterogeneous aetiology to their speech difficulties, therefore research on speech is often focused on specific diagnoses rather than the broader population of individuals with ID. Childhood apraxia of speech has been reported in ASD (Dziuk et al., 2007), childhood dysarthria has been reported in cerebral palsy (Nordberg et al., 2013; Sigurdardottir & Vik, 2011) and Down syndrome is often associated with childhood dysarthria and/or childhood apraxia of speech (Rupela et al., 2016; Wilson et al., 2019a, 2019b). But even within specific subgroups such as ASD, cerebral palsy, and Down syndrome, the heterogeneous aetiology is very much present. Also, structural anomalies, such as cleft lip and palate and malformations in the speech apparatus, can also affect speech and may be associated with many different diagnoses (Persson & Sjögreen, 2011). In this thesis, underlying causes for the participant's speech difficulties have not been investigated and speech sound production has been examined by analysing the participants' phoneme production, regardless of aetiology.

AUGMENTATIVE AND ALTERNATIVE COMMUNICATION

Due to communication difficulties, individuals with ID may need additional support to comprehend their surroundings or to express themselves in a way that others understand (Beukelman & Light, 2020). Individuals with ID have the right to receive the necessary support for communication (including AAC) to engage in education and be provided with the conditions to achieve their goals in school (Convention on the Rights of Persons with Disabilities, 2008).

AAC is defined by the American Speech-Language-Hearing Association (n.d.) as "an area of clinical practice that supplements or compensates for impairments in speech-language production and/or comprehension, including spoken and written modes of communication". AAC can encompass various modalities and are often divided into either aided or unaided AAC. For unaided AAC, no additional equipment is needed, and this includes motions with your own body such as gestures, facial expressions, body posture and manual signs. Aided AAC, includes equipment, such as pictures that can be used individually or on a low-tech communication board (Figure 1), and high-tech speech-generating devices/apps that can utilise both digitised or synthetical speech, images, and text (Beukelman & Light, 2020). A multimodal approach is encouraged to meet the need for different situations (Beukelman & Light, 2020).
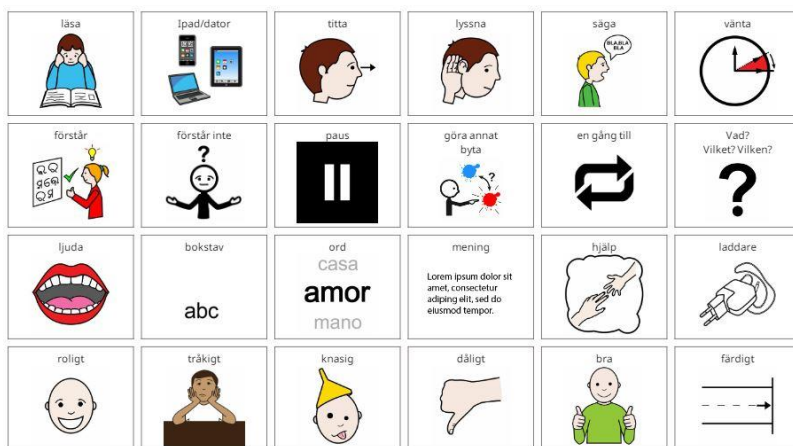
Figure 1. Example of aided AAC, a low-tech communication board with both picture and text used in the test assessment with the students. The communication board is produced in www.bildstod.se. Photo: private.

LITERACY IN INDIVIDUALS WITH ID

According to the UN Convention on the Rights of the Child (1989), all children have the right to receive education, including literacy. There are different ways of defining literacy. The National Early Literacy Panel (2008) defines conventional literacy skills "as decoding, oral reading fluency, reading comprehension, writing, and spelling". Therefore, for an individual to become a reader, the early conventional literacy instruction needs to address phonemic awareness, phonics, vocabulary, fluency and text comprehension (The

National Reading Panel, 2000). It can also be a broader definition of literacy or a more narrow view. Owens (2008) defines literacy in broader terms.

> Literacy is the use of visual modes of communication, especially reading and writing. But literacy is much more than just letters and sounds. Literacy encompasses language – academic and cognitive processes, including thinking, memory, problem solving, planning, and execution – and is related to the other forms of communication (Owens, 2008, p. 356).

In contrast, a more specific, narrow term – "print literacy" – is used and defined by Erickson and Koppenhaver (2020):

> …print literacy, which means reading and writing traditional orthography, or alphabet letters, for meaningful purposes. (Erickson & Koppenhaver, 2020, p. xvi)

The definition of literacy by Erickson and Koppenhaver does not include "idiosyncratic, nonconventional, and graphic-symbols-related behaviors" (Erickson & Koppenhaver, 2020, p. xvii). This is not meant to exclude the students with severe communication difficulties, but instead to enhance everyone's right to focused instructions, potentially leading to conventional reading. This more specific, narrow definition of literacy forms the basis for this thesis. Even though the thesis focuses on literacy as a set of individual skills, we acknowledge that the skills are clearly highly complex and are intertwined with a range of practices and other communication forms in everyday life.

EARLY LITERACY SKILLS

Early literacy skills refer to the foundational abilities and knowledge that children often develop before they formally start reading and writing. In the report from The National Early Literacy Panel (2008), some of the most important early literacy skills were identified, such as alphabet knowledge, letter-sound knowledge, phonological awareness, phonological memory and rapid automatic naming of letters, digits, object, and colours. These skills lay the foundation for more advanced reading and writing abilities. In this thesis, two of these skills will be addressed: letter-sound knowledge and phonological awareness.

For individuals with ID, acquiring letter-sound knowledge and phonological awareness is often challenging (Dessemontet et al., 2017). Having knowledge

of the alphabet's letters and knowing how they are written and how they sound is a foundation for learning to read words (The National Early Literacy Panel, 2008). However, students with ID require more time to establish this knowledge (Allor et al., 2014).

It has been widely shown that phonological awareness is an important foundation and one of the most reliable predictors of the development of conventional reading skills (The National Reading Panel, 2000). Phonological awareness refers to the knowledge of the individual sounds that make up words and involves the ability to recognize and manipulate these sounds, such as blending separate phonemes together to form a word or segmenting a word into its individual phonemes (Scarborough & Brady, 2002; Stackhouse & Wells, 1997).

Early literacy skills are often lower in students with ID than their typically developing peers (Dessemontet et al., 2017; van Tilborg et al., 2014). Several studies have explored interventions that aim to enhance both phonological awareness and letter-sound knowledge in students with ID in need of AAC. The results of the Cochrane review by Reichow et al. (2019) (n=352) showed that early literacy interventions are moderately effective for improving phonological awareness and letter-sound knowledge in children and adolescents with ID. All studies provided the intervention in school settings.

Few studies suggest that phonological awareness may not be a prerequisite for learning to read in this population. In the study by Cossu et al. (1993), some of the participating students with Down syndrome learned to read but still failed to successfully complete tasks involving phonological awareness. On the other hand, understanding the instructions to phonological awareness tests can sometimes be difficult for students with ID, making test scores difficult to interpret (Morton & Frith, 1993). This highlights the need for accommodations (e.g. AAC) during the testing of literacy skills in order to ensure that students with ID are able to demonstrate what they understand.

BECOMING A READER

In the framework of the Cognitive Foundation of Reading (Hoover & Tunmer, 2020), the well-known theory of the Simple View of Reading (Hoover & Gough, 1990) is included and illustrates that reading comprehension depends on both language comprehension and word recognition (decoding). If either of these two components is missing, reading comprehension cannot occur. Simply being able to decode without understanding the meaning of the word

is insufficient for achieving reading comprehension. Likewise, understanding a language but lacking the ability to decode means that reading comprehension cannot been attained. Individuals with ID often experience difficulties with both language comprehension (Jones et al., 2006) and word recognition (Lemons et al., 2013; Ratz & Lenhard, 2013). Therefore, focusing on both comprehension-based and phonics-based reading approaches is likely important for achieving reading comprehension.

As stated in Erickson and Koppenhaver (2020), the US Department of Education (2015a) have reported that students with disabilities have a 2.5-fold higher likelihood of reading below basic levels of achievement. These students are three times less likely to read at proficient levels and five times less likely to read at advanced levels compared to their peers of the same age who do not have disabilities.

Comprehension-based literacy approach

Many students with ID can benefit from a comprehension-based literacy approach. This method aims to broaden the comprehension of the written words and focus on the ability to extract meaning from text (Castles et al., 2018). It is important to monitor the student's comprehension of the words or text. The comprehension-based literacy approach often includes working with text by using motivating materials and conceptual cues (i.e. pictures or conversations to promote the comprehension of the text). This supplemental material is expected to reduce the cognitive effort required from the students and by doing so, it aims to enhance the learning process (Nelson et al., 2001).

The comprehension-based literacy approach includes an important focus on comprehension and therefore differs from the common teaching approach, sight words, which uses a logographic approach to reading (Browder et al., 2006). With the sight words method, students focus on memorising specific words that they often use in their day-to-day lives, but the students may struggle when faced with new, untaught words and the approach may fail to provide students with a comprehensive understanding of the word.

A meta-analysis by Suggate (2016) and a comprehensive overview by Browder et al. (2006) reported that comprehension interventions are positively associated with intervention outcomes. In a Swedish study conducted by Tjus et al. (1998), a computer intervention employing the comprehension-based Alpha Interactive Language Series was used for 13 children with ASD and varied cognitive function. The child was asked to put together written words

into sentences and then received confirmation through speech synthesis and an animation illustrating the meaning of the sentence. The results showed an improvement in word and sentence reading and a significant increase in phonological skills. The comprehension-based application used in our intervention, Animega-interactive sentences (-is) (Heimann & Lundälv, 2020) represents the fourth generation of this intervention developed from the initial Alpha programme.

Phonics-based literacy approach

The phonics-based literacy approach involves pronouncing the sound associated with each individual letter or letter combination, followed by blending these sounds together to recognise an entire word. Therefore, early literacy skills, phonological awareness, and letter-sound knowledge provide a very important foundation for the phonics-based approach. Teaching with a phonics-based approach includes instruction on letter sounds, decoding, and encoding (Castles et al., 2018).

Yorke et al. (2020) conducted a systematic review targeting students with ID in need of AAC and interventions adapted for this population. In this review, 20 out of 24 studies consistently reported positive improvements in targeted tasks following interventions. The study, specifically focused on phonological awareness, letter-sound correspondence, and decoding interventions. Out of 24 studies, seven were conducted based on the Accessible Literacy Learning (ALL) developed by Janice Light and David McNaughton (Tobii Dynavox, n.d.), which is the phonics-based approach that is also used in the intervention that was applied in the research studies presented in this thesis.

The research presented by Browder et al. (2012) assessed the efficacy of a comprehensive early literacy curriculum encompassing phonics and phonemic awareness, comparing it to an approach focused on sight words. The study involved 93 students with severe developmental disabilities, spanning from kindergarten to 4th grade. The findings revealed that students following the multicomponent early literacy curriculum achieved notably higher average literacy scores compared to those in the sight word programme, with effect sizes ranging from small to moderate (.30–.49). Further analysis suggested that proficiency in phonics played a primary role in the distinctions between the two curriculum approaches and is therefore an important component in enabling students to achieve conventional literacy.

The students included in this thesis also participated in a study examining the development of literacy (Palmqvist et al., 2023). In this study, 123 students received either a phonics-based intervention, a comprehension-based intervention, or a combination of both. The results showed that in terms of phonological awareness, the combination of a phonics-based and a comprehension-based reading intervention resulted in stronger development compared to the other groups. In summary, a combined and structured approach to reading instruction is beneficial for the early literacy development of beginning readers with mild, moderate, and severe ID who also benefit from AAC.

MOTIVATIONAL FACTORS INFLUENCING LITERACY

The framework of the Cognitive Foundation of Reading includes the cognitive keystones essential for acquiring literacy (Hoover & Tunmer, 2020). There are also underlying motivational factors that affect the process, perhaps not directly, but still in a way that exerts an indirect influence. These motivational aspects encompass the student's motivation to learn how to read, their interest in books and reading, and their level of self-efficacy (Chapman & Tunmer, 2003; Habibian et al., 2015). It is important to take all of these elements into account when investigating the development of literacy skills, especially in the context of students with ID (Erickson & Koppenhaver, 2020).

When students with a history of literacy struggles are given access to high-quality programmes, they may initially struggle to find the motivation to apply their improving alphabetic coding skills while reading. This can potentially result in negative reading outcomes and should be taken into account when assessing their progress (Hoover & Tunmer, 2020). It is well known that factors such as self-concept, aspirations and motivation develop in a reciprocal relationship with expectations and support from one's surroundings, including teachers and parents (Vygotskij, 1978).

CONNECTIONS BETWEEN SPEECH AND LITERACY

Proficiency in oral language plays a fundamental role in later literacy development (Snowling, 2005). However, it is worth considering the potential for reciprocal causation, where causal relationships operate in both directions by enhancing the accuracy of underlying linguistic representations (Brady et al., 1994; Dodd & Gillon, 2001; Huettig & Pickering, 2019; Kolinsky, 2015; Kolinsky et al., 2021). In this scenario, a correlation may exist between speech production and literacy skills, with literacy skills potentially being able to predict speech sound production. Therefore, even though phonological

representations and speech production skills usually develop before literacy instruction and literacy acquisition, it has been suggested that learning to read and spell can refine phonological contrasts and affect the quality of speech (Nation & Hulme, 2011; Rastle et al., 2011; Saletta, 2015; Saletta et al., 2016). In addition to the above, for students with severe disabilities, language and literacy skills sometimes develop together at the same time (Hanser & Erickson, 2007), and there is not necessarily one skill or area of knowledge that must be established before the other (Erickson & Koppenhaver, 2020) as a primary or foundational capacity. This situation provides a strong impetus to work with literacy among students with ID and communication difficulties.

Children who struggle with language and speech often face challenges in reading aloud, reading comprehension, spelling, and writing (Stackhouse & Wells, 1997). The opposite relationship holds true as well. Those who struggle with spelling and writing often experience difficulties in speech and language, including articulation, word mobilisation, and grammar. According to Stackhouse and Wells (1997), this is not merely coincidental. The foundation for speech is in several aspects the same as the foundation for literacy – the speech processing system. This system displayed in Figure 2 visualises the connection between the speech processing system, with both speech and literacy, and their mutual impact on phonological awareness. If there are deficiencies in the speech processing system, it can affect speech, phonological awareness, and literacy.
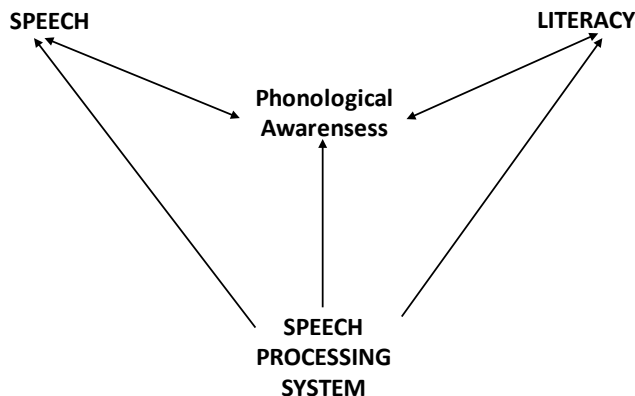
Figure 2 The connection between speech and literacy development (Stackhouse & Wells, 1997). Reprinted with permission from the publisher.

While difficulties with verbal short-term memory are associated with ID, especially for Down syndrome (Schuchardt et al., 2010), visual working memory can sometimes be a relative strength (Frenkel & Bourdin, 2009; Laws, 2002). By taking advantage of the strong visual memory capacity to compensate for the deficiency in verbal short-term memory, reading has been suggested as a strategy to improve speech for children with Down syndrome (Buckley & Bird, 1993). Understanding the visual structure of a written word may help an individual overcome challenges in verbal short-term memory, as the visual representation can be associated with its phonological form for spoken output.

LITERACY INTERVENTIONS AND SPEECH OUTCOMES

Research investigating the effect of early literacy/literacy interventions and speech production in students with communication difficulties with/without ID is limited but interesting since it informs causal hypotheses. A few studies have investigated correlations between early literacy skills and quality of speech sound production in students with ID and communication difficulties (e.g. Barton-Hulsey et al., 2018; Burgoyne et al., 2021). While observational studies are important in showing whether a connection between literacy learning and speech quality exists, determining causality in this relationship is difficult. However, this relationship has been further investigated in intervention studies presented below, where literacy instructions have been used for students with ID and where a possible effect on speech production has been explored.

In the early 1990s, Buckley and Bird (1993) presented their observations and research findings where they found support for the idea that reading was a pathway to speech for children with Down syndrome. In the study by van Bysterveldt et al. (2010) involving ten children with Down syndrome aged four years and four months to five years and five months, an integrated intervention approach was implemented with a focus on speech, letter knowledge, and phonological awareness. The intervention involved joint storybook reading at home and speech therapy with computer-assisted instructions, focusing on phonological awareness and letter knowledge at a professional healthcare centre. The results indicated a statistically significant improvement in speech sound production of both trained and untrained words. However, there was only partial, non-significant improvement in phonological awareness and letter knowledge. The study focused on pre-school children who were still in the speech development stage. It is therefore also important to further investigate the relationship between speech, phonological awareness, and letter-sound knowledge among older, school-aged children with different levels of ID and various diagnoses.

Pagliarin et al. (2022) included three boys with childhood apraxia of speech without ID aged between 5.3 and 5.8 years in an integrated intervention focusing on phonoarticulatory awareness, motor skills, and literacy. None of the three participants were literate, and significant emphasis was placed on visual, auditory, and tactile cues during the introduction of new graphemes. The aim was to assess performance in a speech accuracy task before and after the intervention, with a follow-up assessment conducted one month after the final treatment. There was an improvement in the speech accuracy task, considering their deficit levels both after the final treatment and one month later.

Gillon (2000) demonstrated significant gains following intensive phonological awareness training, not only in phonological awareness and literacy, but also in speech among children with speech impairment without ID. Inspired by Gillon's result, Kennedy and Flynn (2003) attempted to replicate the methodology with a group of students diagnosed with Down syndrome. However, Kennedy did not observe comparable statistical outcomes in speech production. Despite this, Kennedy reasoned that the students with Down syndrome received significantly less training (8 hours compared to the 20 hours of training in Gillon's study) and that this could play a role for these students.

When looking at disabilities other than Down syndrome, Light et al. (2008) conducted a case study in which an 8-year-old girl with multiple disabilities, who used AAC, improved her literacy skills through the ALL curriculum. The improvement in her literacy skills also positively aligned with language and communication skills. Light and McNaughton (2019) continued to investigate speech production in their research on literacy and described improvements in both language and speech production in ten children with varied level of ID and communication difficulties after literacy intervention. In a study involving 13 children with mixed ID and ASD, participants participated in an intervention using a comprehension-based programme (an earlier version of Animega-is) (Tjus et al., 2001). Over time, the children demonstrated an increase in verbal expression.

The prior research described above has often lacked a comparison group, and the number of participants was often small. Furthermore, speech has not been explored in relation to different literacy interventions, such as phonics and comprehension-based approaches. Additionally, existing intervention studies have mainly focused on the Down syndrome population rather than a broader ID population, leaving questions about generalization of the results.

It is important to note that not all evidence supports a connection between reading and enhanced speech outcomes. Burgoyne et al. (2012) assessed a study on the impact of a language and literacy intervention for children with Down syndrome. It was noted that although the students enhanced their reading skills, this improvement did not extend to expressive and receptive vocabulary, expressive information, and grammar. A longitudinal study by Laws (2010) compared a group of individuals with Down syndrome, some of whom were beginning readers and some of whom were not, with a group of proficient readers with Down syndrome. Over the course of two years, the proficient reader group showed a trend towards higher scores in the percentage of correctly produced phonemes, but this trend was not statistically significant. Furthermore, the study did not find any significant interaction between improvements in speech scores and reading proficiency (regardless of whether individuals were non-readers or competent readers). Therefore, the study concluded that there was no substantial evidence indicating a link between reading and speech proficiency. Additionally, Laws (2010) conducted a literature review on the use of reading as an intervention for speech development. Although several studies in the review indicated associations between reading and other functions, "there was little clear evidence that reading was the driver in these relationships" (p. 153).

EDUCATION AND COMPUTER-ASSISTED INSTRUCTION FOR STUDENTS WITH ID

SWEDISH SCHOOLS FOR STUDENTS WITH ID

Sweden ratified the United Nations Convention on the Rights of the Child in 1989 and the United Nations Convention on the Rights of Persons with Disabilities in 2008 and will adhere to the provisions outlined in these conventions. This means that according to Article 28 the Convention on the Rights of the Child, all students have the right to education, and as stated in Article 24 of the Convention on the Rights of Persons with Disabilities, reasonable adaptations must be provided based on individual needs.

Many of the students with ID in Sweden attend a non-inclusive school setting (Skolverket, 2023). Students between 7-16 years have the option to attend compulsory school for students with ID, which has an adapted curriculum (Wilder & Lillvist, 2022). Between 17-21 years, a voluntary school for students with ID is available. These two schools include both special teaching

strategies and individualised material (Andersson, 2020) and are typically organised in groups with a higher than typical staff to student ratio. However, it is also possible to follow the adapted curriculum while placed in a mainstream class.

The adapted curriculum is divided into two different levels. For those with mild to moderate ID, the emphasis is on academic subjects, whereas for students with more significant ID, the focus shifts towards essential life skills and subjects relevant to daily living. Historically, instruction for students with ID has lacked a focus on reading and has instead focused on social and caring aspects (Browder et al., 2006). The Swedish Schools Inspectorate has been critical of the schools for students with ID for their focus on nurturing rather than academics, and these schools have started to shift their focus (Skolinspektionen, 2010, 2020).

What literacy instruction is to entail in Swedish schools for students with ID has not been well documented. However, preliminary data from the comparison group in the Digital Literacy Learning for Students with Intellectual Disabilities (DiLL) project indicate that the curriculum includes letter-sound knowledge, phonics, and comprehension of texts to some extent. Most of the literacy instructions does not seem to have a structured format.

THE ROLE OF TEACHERS

Teachers are clearly important for the students' educational development, as they provide support and create an environment beneficial to learning (Erickson & Koppenhaver, 2020; Park et al., 2019). In order to create a scaffolding teaching environment, it is important to set challenges and tasks at a level close to what the student has already mastered, as described by Vygotsky (1978), using the concept of the "zone of proximal development". The idea is that for learning to occur, children need to gradually gain skills and knowledge with the support of a teacher, parent, or more experienced peer. The use of language that is appropriate for the students' developmental level, collaboration, positive reinforcement and constructive feedback are important aspects of scaffolding (Wood et al., 1976). The zone of proximal development and Tomasello's sociopragmatic usage-based theory (2003) highlight the significance of social interaction and collaboration in learning, as well as the role of teachers or knowledgeable adults in supporting children's cognitive development. However, teachers may face challenges in what to expect from the student and how to provide optimal learning opportunities for students with ID and communication difficulties (Johnson & Semmelroth, 2014).

A recently published report by FUB (2023), included the results of a survey of 408 parents of students with ID. Many parents answered that their children did not receive sufficient education from professionally trained staff. This means that other staff members in the team take responsibility for instruction during large portions of the child's education. This lack of pedagogical expertise can affect a student's ability to reach their full potential and can hinder their learning and development. The results from the report also indicate that students who consistently receive instruction from qualified teachers are more likely to have better opportunities to progress in their learning, and the child's parents are also more likely to be satisfied with the education the child is receiving.

The report from FUB (2023) also shows that teachers' educational knowledge and understanding of students' abilities are crucial for their learning and development. To be eligible to teach in school for students with ID, both a teacher qualification and special education training with a specialisation in ID are required. However, there is a significant shortage of qualified teachers in the schools for students with ID. The majority of teachers (approximately 80%) have a university degree in education but many lack official certification and eligibility in at least one subject (Skolverket, 2022). Support staff are also frequently involved in teaching, even though many may not have sufficient knowledge of special educational needs or literacy learning. Teachers often have many different roles, which include both taking care of the students' basic needs and teaching one-on-one in classrooms (Östlund, 2017).

COMPUTER-ASSISTED INSTRUCTION

The development of mobile technology has made digital media and AAC more accessible and affordable for an increasing number of children (McNaughton & Light, 2013). These tools can make it possible for children with ID to communicate and learn, addressing their specific needs for support through multiple sensory channels and repeated motivators (Thunberg et al., 2011). Animations and video presentations may also be more effective in conveying information than picture presentations (Van Laarhoven et al., 2010). Studies have demonstrated that digital tools not only enhance attention and memory but also serve as motivating and entertaining resources during the learning process (Fälth et al., 2013; McNaughton & Light, 2013; Svensson et al., 2021). By implementing digital tools in school settings, there are more opportunities to support early literacy and enhance the development of literacy skills for students with ID and communication difficulties (Ahlgrim-Delzell et al., 2016;

Fälth et al., 2013; Goo et al., 2020; Nakeva von Mentzer et al., 2020; Tjus et al., 2001).

The digital tools can have two different aims: to compensate for communication and reading difficulties (e.g. AACs and the other for training an ability. Both digital tools are important to provide for students in need of AAC. The aim of the applications used in this thesis is for training purposes.

Studies on training various literacy skills in students with ID have been carried out with promising results (Yorke et al., 2020). Goo et al. (2020) demonstrated the effectiveness of using a digital media tool to provide visual aids in the teaching of phonemic segmentation to elementary students with mild to moderate ID. In another study, Ahlgrim-Delzell et al. (2016) designed a phonics-based reading curriculum specifically for iPads, which yielded in better results for the 12 students who received this instruction compared to the control group. However, Nakeva von Mentzer et al. (2020) found limited overall benefits for students with Down syndrome when using intensive computer-based phonics (GraphoGame) though individual students did show improvements in alphabetic decoding skills, particularly with the trained words.

There have been various approaches to teaching sight words, including the use of computer programmes (e.g. Heimann et al., 1995; Hetzroni & Shalem, 2005; Tjus et al., 1998), and tablets (e.g., Caron et al., 2018; Holyfield et al., 2020). To enhance interaction during computer-assisted instruction, it is important to promote joint media engagement in order to enhance children's engagement in activities (Ewin et al., 2021). Research by Heimann et al. (1995) and Tjus et al. (2001) has shown that joint media engagement as important for enhancing communication outcomes in children with mixed ID and ASD.

Despite the potential advantages, there are currently only a limited number of applications designed for individuals who require AAC with the option to use the access method that works best for them, whether it is touch, eye gaze, or scanning, in order to create the optimal conditions for literacy learning. Also, it is important to note that the applications alone are likely not sufficient to teach students how to read. The role of the teacher in structuring the learning environment, providing clarification, and maintaining the students' focus and motivation seems crucial for achieving educational success in computer-assisted instruction (McTigue et al., 2020).

EXPRESSING VIEWS

Sweden has ratified the United Nations Convention on the Rights of the Child and the more specific United Nations Convention on the Rights of Persons with Disabilities and is therefore obligated to adhere to the provisions of these agreements. It is explicitly stated in both of these conventions that children have the right to express their views. Specifically, Article 7 in Convention on the Rights of Persons with Disabilities states:

> States Parties shall ensure that children with disabilities have the right to express their views freely on all matters affecting them, their views being given due weight in accordance with their age and maturity, on an equal basis with other children, and to be provided with disability and age-appropriate assistance to realize that right.

In essence, Article 7 emphasises the need to ensure that children with disabilities have the same rights and opportunities as other children. It stresses the importance of considering the best interests of the child, respecting their right to express their views, and providing appropriate support to enable them to participate fully in decisions that affect them.

Lundy (2007) conceptualized a model for implementing Article 12 in the Convention on Rights of the Child with four interrelated fundamentals: 1) Space – the child must be given the opportunity to express themselves; 2) Voice – The child must be given the right conditions to express their views; 3) Audience – the views must be listened to; and 4) Influence – The child's views must be taken into account, if appropriate. All students, but especially those with ID and communication disorders, are dependent on adults to make their views available to be expressed and heard.

In order to ensure that the appropriate support is provided, AAC is crucial in many cases to enable individuals to express themselves. It is, of course, important for all individuals to have their own personalised AAC to communicate, but there are also methods with a more universal design that can be used for many individuals to complement their own AAC. When interviewing or providing questionnaires to individuals with ID and/or communication difficulties, the questions can be difficult to understand and to answer (Santoro et al., 2022). One method that has proven effective for individuals with communication difficulties is a pictorial visual framework called Talking Mats (Murphy, 1998; Murphy & Cameron, 2008; Stans et al., 2019). Previous studies have primarily included individuals with various

diagnoses, for example cerebral palsy, Huntington's disease, dementia, and learning disabilities (e.g., Buchholz et al., 2019; Cameron & Murphy, 2002; Murphy, 1998; Murphy & Cameron, 2008; Murphy et al., 2010; Murphy et al., 2005). While most research on Talking Mats has centred on adults, there are also studies that have applied this method to children with ID. Talking Mats has been utilized to facilitate the expression of views, to determine goals, and engage in collaborative decision-making (Backman & Karlsson, 2021; Bunning et al., 2017; Henderson et al., 2015).

When an individual has ID, opinions and views are often gathered through others such as parents, caregivers, or other professionals. This is especially true when it involves children with ID who may also experience communication difficulties (Stafford, 2017). However, even if it presents challenges, both clinicians and researchers need to try to address these challenges and ask for the child's views even when ID or communication difficulties are present.

RATIONALE FOR THIS THESIS

The ability to communicate is of great importance for one's quality of life, participation, and well-being. Using speech as a means of communication is not always a given for individuals with ID and communication difficulties; therefore, if speech can be improved, it provides faster ways to communicate and interact with others. There has been limited research regarding the relationship between speech sound production and early literacy skills for the group of individuals with ID and communication difficulties, and even fewer studies have explored the potential impact of literacy interventions on speech sound production. The existing research, although scarce, primarily focuses on individuals within specific diagnoses, such as Down syndrome. However, the findings from previous studies are not conclusive.

Investigating this possible secondary effect of digital literacy intervention could result in a greater emphasis on literacy intervention in special education as a broader aspect of learning abilities beyond "just" reading proficiency. In addition to test scores that reflect these abilities, we also want to include the perspectives of the students themselves, as well as their teachers, who can provide the outcome of the intervention from their perspectives.

The four studies in this thesis collectively address significant gaps in the existing body of research on speech production and literacy in individuals with ID and communication difficulties.

AIM

The overall aim of this thesis was to examine the associations between speech production and literacy skills in students with ID and communication difficulties and to investigate the potential impact of a literacy intervention on speech production, from the perspectives of both teachers and students with ID and communication difficulties themselves and by comparing test data before and after intervention.

The aims for the four sub-studies were as follows:

 I. To investigate the associations between early literacy skills and speech sound production in students with ID and communication difficulties.

 II. To investigate the perceptions of speech and reading activities by students with ID and communication difficulties and how consistent these are with their test results on speech production and reading ability.

 III. To explore the teachers' perception of the students' development regarding reading ability, speech, and communication during a combined digital literacy intervention including phonics and comprehension-based instructions.

 IV. To investigate if digital literacy intervention affects speech sound production in students with ID and communication difficulties.

METHODS

STUDY DESIGNS

This thesis includes four studies with different study designs (see Table 1). The first two studies included data collected prior to the literacy intervention, and the third is based on data after the literacy intervention. The fourth study is based on data collected both before and after the literacy intervention.

Table 1 Overview of the four study designs, data sources, and analyses.

Study	Design	Data source	Data analysis
I Associations	Cross-sectional descriptive design	Speech sound production, phonological awareness, letter-sound knowledge, and cognition	Correlation and regression analysis
II Students' views	Descriptive design combined with survey design	Speech sound production, word reading assessments and students' ratings of speech and reading activities	Correlations and Friedman's Two-way ANOVA by Ranks
III Teachers' views	Qualitative survey design	Dyad semi-structured interviews with teachers	Qualitative thematic analysis
IV Intervention	Quasi-experimental design	Speech sound production	Generalized linear mixed-effect model

SETTING AND PARTICIPANTS

This thesis is a part of a large project called Digital Literacy Learning for Students with Intellectual Disabilities (DiLL). A total of 137 students enrolled in Swedish schools for students with ID were recruited to the DiLL project through their teachers. The students were aged between 7 and 21 at the beginning of the project. The goal was to include students with different diagnoses and ages, who relied on AAC to understand others and/or express

themselves. The teacher assessed that the included students had weak reading skills, they were able to read a maximum of about 20 words and lacked independent decoding ability (had not "cracked the code"). Comorbidity such as ASD, ADHD, and/or sensory impairment was reported to be common among the students. Students in need of hearing aids and/or visual aid, used these during testing.

Students and teachers were recruited to the DiLL project in two rounds due to the large number of students and because the different groups receiving interventions needed to start at different times. The schools were assigned to either the comparison group or one of the project's three intervention groups: phonics-based approach, comprehension-based approach, or the combined group with both approaches. This was based on both geographical location and chronological age.

Telephone interviews with caregivers/legal guardians and digital questionnaires filled out by teachers were used to gather demographic and diagnostic information.

The students in the DiLL project exhibited a range of expressive speech difficulties, varying from mild to severe impairment. All students had access to some form of AAC in their daily school environment. This AAC support was provided either for expressive purposes, comprehension support, or both. The use of AAC forms and methods among the students was diverse, including manual signs, pictorial aids, and technology-based tools, such as speech-generating devices. It is worth noting that most students utilized multiple modes of AAC.

Not all participants were involved in each individual study. Some students were unable to participate in all parts of the test battery, and due to COVID-19, some students were unable to complete the literacy intervention or attend the test occasions. An overview of all participants in the four studies is presented in Figure 3.
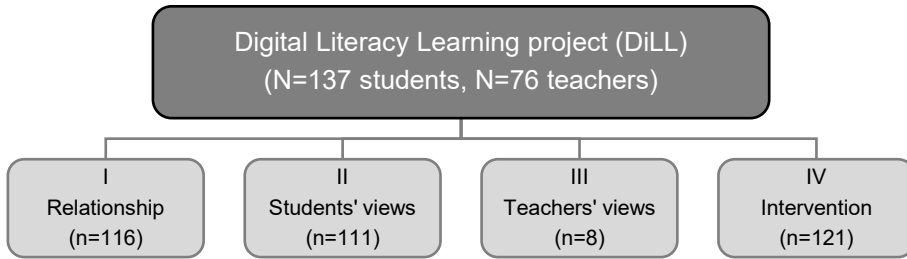
Figure 3. Overview of participants in the four studies.

Study I *Associations* included 116 students (65 boys and 51 girls) aged between 7-21 years, with a mean age of 13.6 years. Eleven students had varying degrees of hearing impairment, ranging from mild to severe. During testing, the students who required hearing aids used them. Additionally, 39 students had visual impairments, and the vision of five students was not fully corrected by corrective lenses.

Study II *Students' views* included a sample of 111 participants (63 boys and 48 girls). Ages ranged from 7 to 21 years, with an average age of 14 years. The students' language comprehension was evaluated using a digital questionnaire completed by their teachers.

Study III *Teachers' views* included eight teachers from the combined intervention group who chose to participate in a digital dyad interview. The teachers had an age range between 30-55 years old and instructed 13 students (5 mild ID, 7 moderate ID, and 1 unknown level).

Study IV *Intervention* included 121 students from all four groups (comparison n=28, phonics n=30, comprehension n=29 and the combined n=34). Their age ranged from 7-21 years with a mean of 13 years, 8 months.

For an overview of the student participants in Study I *Associations*, Study II *Students' views* and Study IV *Intervention*, see Table 2. The table shows the number of participants, level of ID, and diagnosis in addition to ID. There is also information about the student's different means of communication in addition to their potential speech. A description of the students in the different groups in Study VI *Intervention* is presented in Table 3.

Table 2. A descriptive table of the participants in studies I *Associations*, II *Students' views* and IV *Intervention*, displaying the number of participants (boys and girls), level of ID, diagnoses additional to ID, and means of communication that were used.

Study	I Associations	II Students' views	IV Intervention
Number of students (boys/girls)	116 (65/51)	111 (63/48)	121 (69/52)
ID level			
Mild	39	40	39
Moderate	62	61	67
Severe	11	6	12
Unknown	4	4	3
Diagnoses			
ID – no second diagnosis	19	23	21
Autism spectrum disorder	33	26	32
Down syndrome	25	24	27
Cerebral palsy	11	11	11
Rare	28	27	28
Means of communication			
Nonverbal communication[a]	83	79	88
Pictorial support[b]	71	70	75
Manual sign	78	78	84
Speech generating device	21	16	18

Note. [a]Nonverbal communication includes facial expressions, gestures, eye contact, vocalization, and body movement. [b]Pictorial support includes pictorial schedules, single pictures, picture communication boards, and picture communication books.

Table 3. A descriptive table of the participants in Study IV *Intervention*, displaying the number and percent of students divided in the four different groups and their level of ID.

Group	Comparison	Phonics	Comprehension	Combination
Number of students	28	30	29	34
ID level				
Mild	5 (18%)	8 (27%)	15 (52%)	11 (32%)
Moderate	17 (61%)	16 (53%)	13 (45%)	21 (62%)
Severe	6 (21%)	4 (13%)	-	2 (6%)
Unknown	-	2 (7%)	1 (3%)	-

DILL LITERACY INTERVENTION

The literacy intervention was provided using two applications that were both adapted to individuals who may require assistive technology, such as eye-tracking, scanning, or other adaptations (e.g. extended response time). For the comprehension-based intervention, Animega-is was used, and for the phonics-based intervention, ALL was used.

The teachers received four hours of training on each app depending on what intervention group they were allocated to. The workshop was provided in a digital format due to COVID-19 pandemic restrictions. The teachers were first introduced to the DiLL project, then the demonstration of the application(s) was given followed by time for the teachers to practice and ask questions. The teachers were given access to the videorecorded workshop online to enable them to watch it as many times as they wished. Written instructions were sent to the teachers, including AAC material, as an option to use for preparation before and during the lessons with the literacy application with the students. The teachers were also told that they were welcome to ask questions via e-mail or phone at any time.

The intervention would be provided to the students over a period of 12 weeks, with 90 minutes per week. This time could be allocated based on the individual needs of the student. Each week, the teachers filled out a short questionnaire online, which asked for the amount of time they worked using the application(s), which items/levels had been used, how they perceived the students' engagement, and with whom the students worked.

ANIMEGA-INTERACTIVE SENTENCES

The comprehension-based application, Animega-is, was developed by Topic DOS AB (Heimann & Lundälv, 2020). The application included various levels of complexity, incorporated comprehension assessments, and encouraged exploration with the guidance of a teacher.

Animega-is has two different learning modes (Figure 4). One of these is to create sentences from words that generate corresponding animations or video clips (Create/Skapa) and the other is to choose a sentence that corresponds with presented animations or video clips (Test/Testa). In the "Create mode", learners could generate sentences using text buttons, which were then supplemented with corresponding animations or video clips. For an example of how an animation was made in different steps, see Figure 5. In the "Test

mode", learners assessed their proficiency by observing the animation, selecting words, and constructing a sentence that best described what they saw.

The language material and accompanying animations served as motivation and provided opportunities for learners to express their creativity and thoughts, and engage in conversations. The application's foundation lies in the use of recasts (Clarke et al., 2017), and it aims to facilitate the collaborative construction of meaning through text, animations, and supportive interaction, with the goal of achieving error-free comprehension.
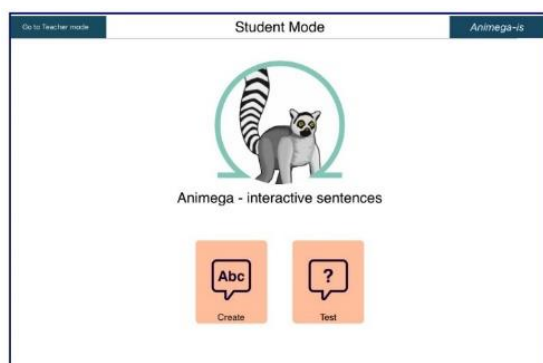

Figure 4. Starting page of the Animega-is application, choose Create or Test. Published with permission from Topic DOS.
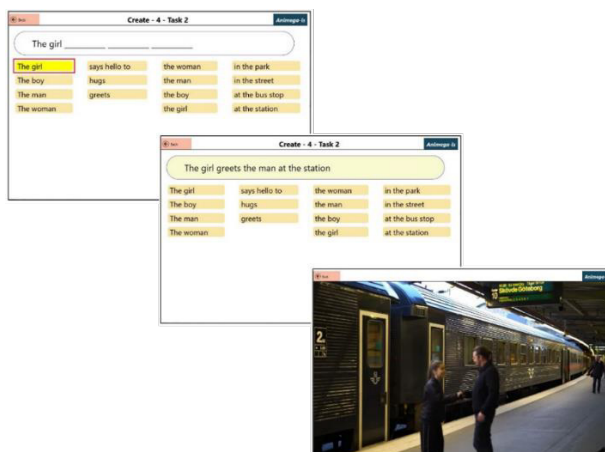

Figure 5. Choose the words you want to say. The sentence is read with speech synthesis, and the animation is displayed on the screen. Published with permission from Topic DOS.

ACCESSIBLE LITERACY LEARNING

For the phonics intervention, the ALL application was utilized (Tobii Dynavox, n.d.). The ALL program was developed by Light and McNaughton, and the digital application comprised modules for foundational literacy skills, blending direct phonics-based instruction with meaningful comprehension-oriented reading activities, aligning with the guidelines of the National Reading Panel (2000). In ALL, the teachers were instructed to only use this application's modules for phonics-based instruction: sound blending, phoneme segmentation, letter-sound correspondences, and word recognition. An example from the application's Teacher mode with all the stages and tasks can be seen in Figure 6. Further, examples of the task with Letter Sound Correspondence and Phoneme Segmentation can be seen in Figure 7 and Figure 8, respectively. In Letter Sound Correspondence, the teacher or digitised voice pronounced the letter and the student pointed to the corresponding letter. For Phoneme Segmentation, the teacher or digitised voice pronounced the target word and the student pointed to the corresponding picture.

The application featured three instructional modes: full instruction, targets only, and teacher assisted. In the present study, the teacher-assisted mode was recommended to enhance communication between the student and teacher. This mode enabled the teacher to provide instruction, targets, prompts, and feedback, either alone or in conjunction with ALL.
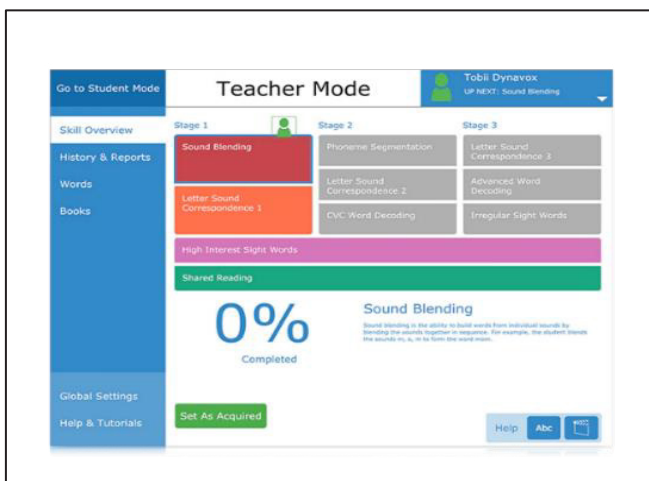
Figure 6 Overview of all stages and tasks in Teacher Mode. Published with permission from Tobii Dynavox (n.d.).
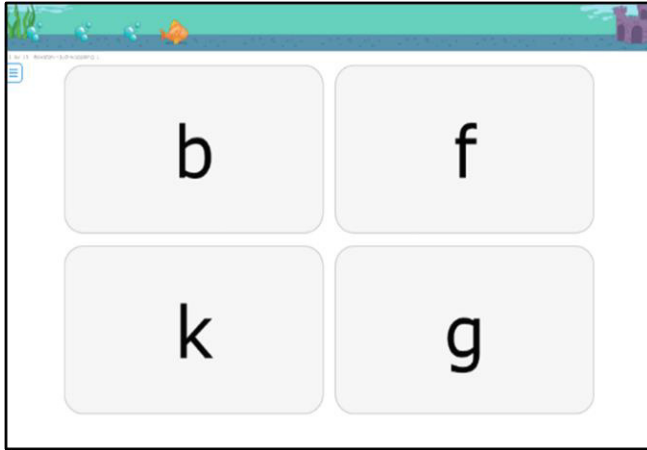
Figure 7 Example from the task, Letter Sound Correspondence 1. The digitised voice or the teacher pronounced the target sound and the student pointed to the corresponding letter. Published with permission from Tobii Dynavox (n.d.).
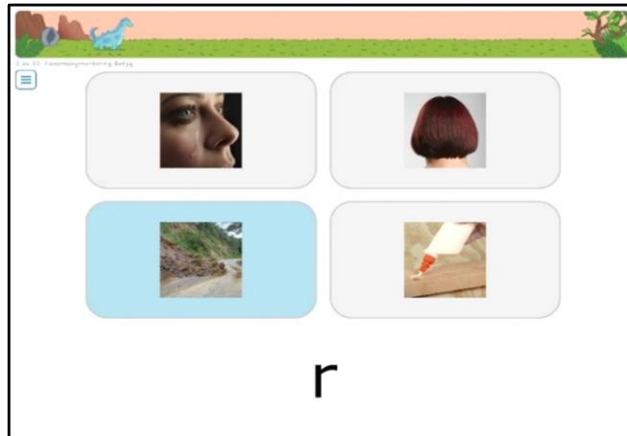
Figure 8 Example from task in Phoneme Segmentation. The digitised voice or the teacher pronounced the target word and the student pointed to the corresponding picture. Published with permission from Tobii Dynavox (n.d.).

DATA COLLECTION

It is important to consider the test administration procedure during data collection when assessing individuals with ID. In some cases, when assessing individuals with ID and communication difficulties, researchers may be able to use tests as designed when they do not rely on verbal responses from the

student. However, many tasks do rely on verbal responses and adaptations are needed, for example, modifying how tasks are presented and/or how the AAC user responds during the test (Barker et al., 2012). Therefore, the norm data of the original tests are sometimes difficult to apply. In the DiLL project, considerations have been made in the selection of both tests and testing procedures to enable the students to participate. With the exception of the speech sound production test, tests have been used that allow responses regardless of speech ability. Some tests have also been modified by reducing the number of tasks. See the description of each test below.

All data for studies I *Associations* and II *Students' views* were collected by three test leaders from DiLL prior to the literacy intervention and also after the intervention for Study IV *Intervention*. The data for Study III *Teachers' views* were collected after the literacy intervention by two researchers from the DiLL project who did not test the students. The following section will present the data collection for speech sound production, early literacy skills, and cognition. It will also present the procedures and materials employed for the interviews with both the students and the teachers.

SPEECH SOUND PRODUCTION

The speech production was included in the analyses of the three Studies I *Associations*, II *Students' views* and IV *Intervention*.

B.A.F. ASSESSMENT OF PHONOLOGY

The assessment of speech sound production was conducted using a sub-test from the Assessment of Phonology [Bedömning av Fonologi] (Frylmark, 2015). For the purposes of this study, the action picture representing a café visit was selected to elicit speech sound production. It consisted of 28 target words representing a total of 138 phonemes, encompassing all Swedish phonemes, though not in every word position (initial, medial, final).

Initially, the students were asked to verbally describe the action picture, aiming to elicit all 28 words through their spontaneous speech. In cases where this was not possible, the administrator would point to specific objects or actions in order to elicit the word and would finally prompt the student to repeat the word after it was pronounced by the test leader. The test sessions were video recorded, and a phonetic transcription of all the target words was made after testing. See the section Speech production analysis below for more details about the analysis.

EARLY LITERACY SKILLS

Early literacy skills were assessed for Study I *Associations*, which included two different assessment materials: MiniDUVAN (Wolff, 2013) and Letter-sound knowledge.

MINIDUVAN

MiniDUVAN is designed to assess phonological awareness in preschool children and consists of a set-up of phonological subtests representing various aspects of phonological awareness. Three subtests from MiniDUVAN were included: Phoneme Synthesis, Phoneme Identification, and Rhyme Identification. To address speech intelligibility challenges, all three subtests utilized a non-verbal response with pictures. Each subtest included two practice items followed by nine test items. If a student gave an incorrect response to three consecutive items, the subtest was discontinued.

In the Phoneme Synthesis subtest, the test leader pronounced a word segmented into three to five sounds. The participant was asked to identify the correct word from three pictures, one of which represented the correct word and two of which were distractors. For instance, the test leader said, "Can you point at /s/ /u/ /n/", with a brief pause (approximately 1 second) between each sound. For the Phoneme Identification subtest, the participant was shown a picture of an object (e.g., a sun) and instructed to point to another picture of an object with the same initial phoneme in its name (e.g. "This is a sun. Sun starts with /s/. Point to the picture that starts with the same sound /s/."). The target phoneme remained constant for all items. Three pictures were presented: one target and two distractors. In the final subtest, Rhyme Identification, the participant was tasked with determining whether two spoken words rhymed (e.g. "do hat – cat rhyme?"). The participant could respond verbally, point to pictures indicating "yes" or "no," or use their own AAC mode. The dependent variable was the total number of correct responses across all subtests (ranging from 0 to 27).

LETTER-SOUND KNOWLEDGE

The letter-sound knowledge task was specifically designed to be used in this study and consisted of eight target letters, evenly divided between consonants and vowels. Four letters were presented in uppercase (L, D, A, and Ö), and four in lowercase (g, o, k, and å), which were selected based on their production characteristics, manner of articulation, and visual representation. In each task item, four letters were displayed in Arial font, size 130, on a sheet of paper (Figure 9). During the task, the student was instructed to point at the letter

corresponding to the test item's sound spoken by the test leader. The dependent variable was the total number of sounds correctly matched to the corresponding letters, with a possible range of 0 to 8.

E	L
D	T
A	H
Ö	B

i	g
o	r
u	p
k	å

Figure 9 The four sheets of paper displaying the test items in letter-sound knowledge.

WORD READING

For Study II *Students' views*, two reading tests were used to assess word reading ability: the OS 64 (Nielsen et al., 1997), Swedish version by Magnusson and Nauclér (2011) and OLAF (Magnusson & Nauclér, 2010).

OS 64

In OS 64, the student was presented with the written word [e.g. katt (cat)] and asked to point at the corresponding picture among four alternatives [kanon (canon), skurk (crook), katt (cat) and hatt (hat)], with one picture having phonological similarity. The words in OS 64 contained construction from CV to multiple syllables. The OS 64 test was reduced from 64 items to two practice items and 15 test items. The test material in OS 64 was also adapted for the student, by replacing the original small, pencil-drawn pictures in the test with Widgit symbols (https://www.widgit.com) for better recognition.

OLAF

In OLAF, the student was presented with a picture [e.g. bok (book)] and was asked to point to the correct written word out of four suggestions [e.g., bur (cage), bok (book), lek (play) and lök (onion)] with different phonological similarities. The OLAF test was reduced to two practice items and 13 test items and used words constructed with consonant-vowel-consonant to multiple syllables.

COGNITION

Caregivers reported diagnoses based on the level of ID, but a test on cognition was also administered to enable control analysis in Study I *Associations*.

RAVEN

To estimate the students' non-verbal IQ, we used Raven's 2 Progressive Matrices Clinical Edition (Raven, 2019). We administered the first three modules, A, B, and C (36 items in total). Participants were instructed to select their answer by pointing to one of the five pictures that completed the figure presented on a sheet of paper. If a participant answered six consecutive items incorrectly, the task was terminated. The student's estimated IQ was determined based on the total number of correct items, considering age norms, with a normative mean of 100 in the population and minimum score of 40.

STUDENTS' VIEWS

To facilitate the students' ability to express their views in Study II *Students' views*, pictorial support was used. Even though some of the students had their own AAC solutions available, a structured picture-based material, Talking Mats (Murphy & Cameron, 2008), was used to ensure that as many students as possible could successfully express their views.

TALKING MATS

The interview procedure followed the concept of Talking Mats. As shown in Figure 10, a three-point visual scale, displaying facial expression images (like, in between/neutral, dislike), was placed at the top of the mat. The two topics (speech and reading activities) were presented one at a time with their respective questions.

The complete interview with the students consisted of 20 questions but for this thesis, seven questions were included in Study II *Students' views*. The selection of symbols representing four questions/options about speech activities, as well as three options for reading activities, were provided to the student. The student would then place the symbols on a mat under one of the facial expressions. The test leader sequentially presented the options representing the questions, asking, 'What do you think about…?' (supplemented with manual signing). Students either independently placed the options on the mat or received assistance from the test leader (e.g. in case of limited motor function), with confirmation obtained directly from the student. The duration of the interview

ranged from 10 to 15 minutes. After each topic (speech and reading activities), students were given the opportunity to confirm and change their choice.
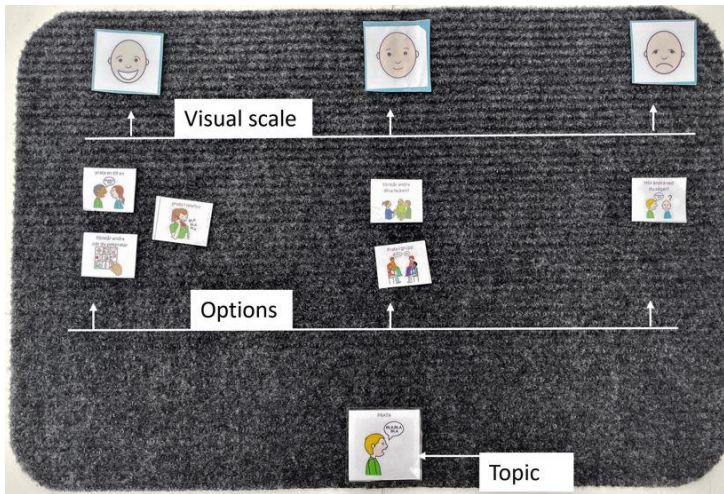
Figure 10 Example of a mat concerning the topic speech activities (Samuelsson et al., 2023). Reprinted with permission.

TEACHERS' VIEWS

For data collection in Study III *Teachers' views*, four semi-structured interviews were conducted. The questions posed concerned the teachers' perceptions of their own participation in the literacy intervention and their students' reading and communication development.

The data collection was conducted as dyadic interviews with two teachers interviewed together. This method is valuable, as the researcher seeks to gather in-depth details, and personal perspectives in individual interviews, while also seeking to observe a level of interaction similar to what occurs in focus groups (Lobe & Morgan, 2021). In dyadic interviews, topics tend to appear more quickly and intertwine more closely with each other compared to focus groups. (ibid.).

The dyad interviews were conducted remotely using the video conference application Zoom in order to comply with COVID-19 pandemic restrictions and to be able to mix teachers from different geographical locations.

ANALYSES

A variety of both quantitative and qualitative analyses were used in this thesis. First, a more detailed description of the speech production analysis is presented below, followed by the statistical analyses for the three quantitative Studies I *Associations*, II *Students' Views*, and IV *Intervention*. Last, the qualitative analysis will be presented for Study III *Teachers' views*.

SPEECH PRODUCTION ANALYSIS

The outcome measurement for speech proficiency was percentage phonemes correct (PPC), which is a calculation of all correct phonemes, both vowels and consonants, produced in the target words.

Shriberg and Kwiatkowski (1982) classified the severity of speech disorders using the percentage calculation of the different phonemes in word production. They looked at the consonants and the vowel production and calculated the percentage consonants correct and the percentage of vowels correct in addition to percentage phonemes correct (PPC).

For the studies in this thesis, the PPC was used to ensure the inclusion of all phonemes in the students' speech production. Since speech difficulties, including both dysarthria and dyspraxia, are commonly found in individuals with ID (Dziuk et al., 2007; Memisevic & Hadzic, 2013; Nordberg et al., 2013; Rupela et al., 2016; Shriberg et al., 2019; Wilson et al., 2019a), it was considered relevant to consider the entirety of both vowels and consonants in speech production. Each phoneme was evaluated as either correctly or incorrectly produced. Accuracy in both place and manner of articulation was required, which means that all substitutions and omissions were considered incorrect. Morphological endings were not included in the analysis. However, allophones were scored as correct.

RELIABILITY

An interrater reliability analysis was conducted on PPC. This analysis was performed on a subset of recordings consisting of 20 samples (14.6%). To assess the consistency between the two raters, ten students were randomly selected from each of the two transcribers' data. This subset represented all five main comorbidity subgroups (ID = 2, ASD = 6, Down syndrome = 7, cerebral palsy = 2, rare/unknown = 3).

Interrater reliability for the PPC was calculated using the intra-class correlation coefficient. The resulting average intra-class correlation coefficient was .997, indicating a high level of agreement. This calculation was based on a two-way mixed method with absolute agreement. Further, the agreement between the two raters on all 138 phonemes was calculated using Cohen's Kappa, with a substantial agreement (κ = .78) (Landis & Koch, 1977).

STATISTICAL ANALYSES

The statistical analyses in this thesis were conducted using IBM Statistical Package for the Social Science for Windows (SPSS version 28) for Study I *Associations* and II *Students' Views*. For Study IV *Intervention*, R (R Core Team, 2022) running under R Studio (2023) was used.

Depending on the size and distribution of data, both parametric and non-parametric tests were used in the three quantitative studies: I *Associations*, II *Students' views*, IV *Intervention*. The chosen level of significance was $p < .05$ for all analyses.

I ASSOCIATIONS
Pearson *r* parametric correlations were used in Study I *Associations*. The data were first analysed with both parametric (Pearson *r*) and nonparametric (Spearman r_s) correlations between the variables and then estimated and compared. Since the results were consistent regardless of the method used, we chose to present parametric correlations.

A multiple regression analysis was used to investigate the variance in speech sound production explained by early literacy skills in relation to speech sound production. The analysis was conducted in two steps. First, age and IQ were added to the model. Second, phonological awareness and letter-sound knowledge were forced into the model. The collinearity statistics of multiple regression analysis did not suggest the presence of multicollinearity. The Durbin-Watson test (2.09) indicated that the residuals were independent (Field, 2013). The interpretation of R^2 followed the guidelines by Cohen (1988): very weak if < 0.02, weak if 0.02 - 0.13, moderate if 0.13 - 0.26, and substantial if > 0.26.

To consider any potential effects of various diagnoses and sensory impairments, a group comparison was conducted using the non-parametric Mann–Whitney U Tests, which was adjusted to account for multiple group

comparisons. A non-parametric test was chosen because of the small subgroups.

II STUDENTS' VIEWS

The visual scale on Talking Mats was transformed to an ordinal scale to enable quantitative calculations (Like = 3, Neutral/In between = 2 and Dislike = 1). Pearson r parametric correlations were used between the summed variables for speech and reading activities and the corresponding test results on speech production and reading ability.

Further, a nonparametric Friedman's two-way analysis of variance (ANOVA) by Ranks was used to compare the difference in the answers regarding the increased demand in reading activity. For follow-up analyses, Dunn's pairwise comparisons with Bonferroni correction were used.

IV INTERVENTION

A generalized linear mixed-effects model was applied to determine whether correct speech sound production changed over time and was influenced by the literacy intervention. The model was fitted using the glmer function from the lme4 package (Bates et al., 2015), and the three intervention groups were assessed separately against the comparison group.

We applied a maximum effect structure (Barr et al., 2013), with variation in both the starting point (intercept) and the slope (relationship between variables) for each participant included as random effects. The alpha level was set at .05 for all effects.

THEMATIC ANALYSIS

For Study *III Techers' views*, a qualitative approach was applied. Thematic Analysis (TA), as described by Braun and Clarke (2006), was used to analyse the data from the teacher interviews. Braun and Clarke have further developed this method, which they have named reflexive thematic analysis (Braun & Clarke, 2022), to emphasise the importance of researcher reflexivity in the analysis process.

The analysis is based on six phases, which are not fixed but serve as guidelines for the procedure. First, familiarisation with the data took place, following the inductive coding of the transcripts. Subsequently, the data was coded with a semantic approach, keeping it as close as possible to the explicit meaning.

Initial themes were then generated and compared against original data and, then refined and defined as themes (Braun & Clarke, 2022).

The author of this thesis conducted the coding of data, then established preliminary subthemes and themes. Three co-authors in Study III *Teachers' views* then participated in the reflexive thematic analysis, refining the preliminary themes collaboratively and aligning them with the research questions.

ETHICAL CONSIDERATIONS

The four studies in this thesis were approved by the Swedish Ethical Review Authority (case number 2019-03845 and 2020-06215).

When carrying out research that involves children, especially children with ID, special considerations need to be taken. Because of this, all participants, teachers, students, and their caregivers received written information including pictorial support with information about the literacy intervention project and a request for written consent. The students' caregivers responded by providing written consent for their child.

In the beginning of the test session, all students were asked if they knew what would happen during the session. The test leader provided verbal instructions and a visual schedule displaying every task included, as well as breaks. The student could choose what they preferred to do during breaks, such as drinking water, eating a snack, or moving around in the room. The students' verbal and nonverbal communication was always respected, and testing was interrupted at any sign of discomfort. Students often had an accompanying adult in the room who was also able to explain and interpret the student's communication when needed for the test leader.

In all studies, considerations were made when reporting the students' various diagnoses to ensure that no student could be identified as an individual. Only the larger groups of diagnoses were counted separately, while all minor or rare diagnoses were grouped together. In a small country like Sweden, rare conditions could potentially be recognizable and easily connected to individuals, and data that could reveal these diagnoses were not included. This practice was also applied in the interviews with the teachers, where the students were not identifiable by the other participating teacher in the dyad.

Concerns may be raised about the test assessments used for this group of students. When conducting this research and interacting with numerous students, the students seemed enthusiastic and eager to participate. There were, however, some rare exceptions where a student was not willing to participate in a portion of the assessment. There are certain gaps in the data due to the need to respect students' verbal and non-verbal communication when an unwillingness to participate in testing was expressed or perceived by the test leader or assisting staff. Students exercised the option not to participate not only during parts of the test assessments but also during the intervention period with the teacher. Two students in the combined intervention group expressed strong resistance to one of the applications very early in the intervention. As a result, these two students switched their intervention group and continued participation only in the group with a single application.

RESULTS

The presentation of the results will focus on the main research questions of each study. First, the relationship between speech sound production and early literacy skills will be presented. Second, the results from the students' perspective and a comparison with the data on speech and word reading skills will be presented. Third, the teachers' perceptions after the literacy intervention will be presented. Finally, the section will conclude with an examination of the quantitative assessments of the students' speech production following the literacy intervention.

I ASSOCIATIONS

A notable variation was observed in the speech sound production skills in the students participating in this study. Together, the 116 students achieved a score of 66.5% on PPC, although this ranged widely from 0% to 100%.

The results from the correlations between speech sound production, IQ, age, phonological awareness, and letter-sound knowledge demonstrated that speech sound production (PPC) was positively correlated with both phonological awareness ($r = .54$, $p < .001$) and letter-sound knowledge ($r = .45$, $p < .001$). Phonological awareness and letter-sound knowledge also had a significant correlation ($r = .60$, $p < .001$). On the other hand, looking at the speech sound production, no significant associations with chronological age and IQ ($p > .05$) were found.

To investigate if early literacy skills independently explained variation in speech sound production, a multiple regression analysis was performed in two steps. In Step 1, age and IQ were inserted to account for the impacts on speech sound production, revealing that these variables explained a small proportion of the variance in the percentage of correctly produced phonemes ($F(2, 113) = 2.875$, $p = .061$, $R^2_{adj} = .03$). The individual contributions of age and IQ to speech sound production were limited. Continuing to Step 2, both phonological awareness and letter-sound knowledge were added, and the outcomes showed that, combined with age and IQ, these variable explained 29% of the variance in phoneme production ($F(4, 111) = 12.791$, $p < .001$, $R^2_{adj} = .29$). When analysing the specific individual effects of the predictors related to early literacy skills, it was evident that phonological awareness and letter-sound knowledge were distinct and positively associated (26%) with speech sound

production, together explaining a moderate to substantial variance of speech sound production for this group of participants.

II STUDENTS' VIEWS

The students were given the opportunity to share their perspectives on speech and reading activities and they proved to be able to do this. The descriptive statistics of the four questions regarding speech showed that most of the students (67%) chose the positive response option (i.e. the happy face) for talking to one person at a time and had a positive view of talking on the phone (68%). Slightly less than half of the students (48%) chose the positive response option for talking in groups and their perception of how others hear what they say (45%). For a detailed distribution of the ratings, see Figure 11.

The descriptive statistics for the reading activities showed that 50% of the students selected the positive response options (i.e. happy face) for letters, while 40% did the same for words, and only 29% selected the positive response option for reading sentences (Figure 12).

Upon analysing the outcomes of the questions concerning reading activities (reading letters, words, and sentences), it was apparent that the responses in the ratings implied that as the complexity of the reading task increased (such as moving from reading letters to words and then to sentences), the students' ratings became less positive. The ANOVA revealed a noteworthy main effect, $\chi^2(2) = 29.81$, $p < .001$. Dunn's pairwise comparisons, with Bonferroni correction for multiple comparisons, showed a significant difference between ratings for reading letters and sentences, where letter reading tasks were perceived more favourably ($p = .001$). However, there were no significant differences between letters and words ($p = .24$) or between words and sentences ($p = .19$).

The correlation analysis between the scored views on speech activities and speech sound production (PPC) showed a weak but significant effect $r(84) = 0.24$, $p = .026$. The correlation between the scored views on reading activities and word reading skills was also significant $r(103) = .21$, $p = .029$.

What do you think about...

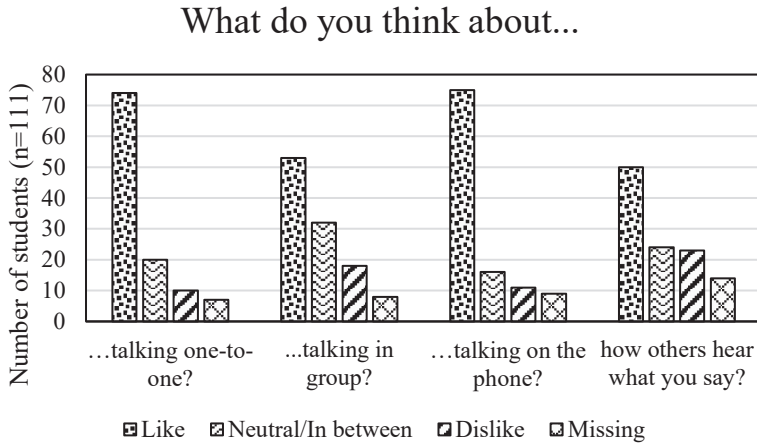*Figure 11. Students' responses to the four questions regarding speech activities (Samuelsson et al., 2023). Printed with permission.*
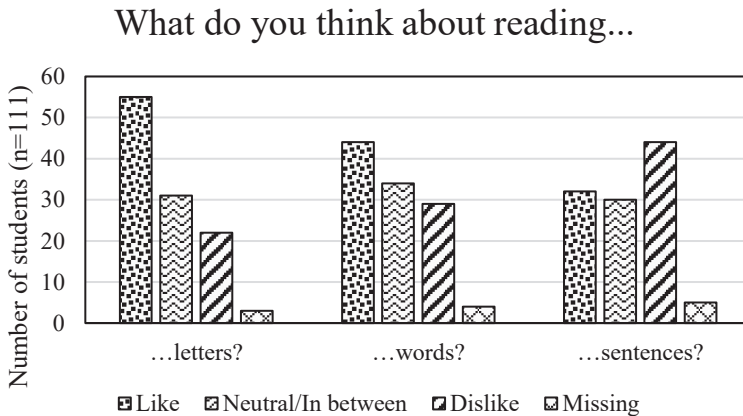
What do you think about reading...

Figure 12. Students' responses to the three questions regarding reading activities (Samuelsson et al., 2023). Printed with permission.

III TEACHERS' VIEWS

The reflexive thematic analysis (Braun & Clarke, 2022) from the eight participating teachers in the combined intervention group resulted in four main themes: The engaging effect of participating in the research project; Digital tools as scaffolding for learning; The impact of a supportive teaching environment; and Student development. In Figure 13, all four main themes with their sub-themes are presented.

The engaging effect of participating in the research project	Digital tools as scaffolding for learning	The impact of a supportive teaching enviroment	Student development
Grow as an individual	Positive effects of these digital tools	The importance of structure and continuity	Cracking the code of reading
Positive support from different stakeholders	Positive to use two types of applications	The teacher's role	Communication develops on different levels
Challenge low expectations on students with ID	Motivating… but less fun in the long run?		…but not wow for everyone

Figure 13. An overview of the themes and subthemes from the reflexive thematic analysis.

The first theme, *The engaging effect of participating in the research project*, focuses on the different positive effects that the student and others around them perceived due to the intervention. According to the teachers, the positive focus on the students' abilities made the students grow as individuals. They also sometimes exceeded expectations, both their own expectations and those of the people around them.

The second theme, *Digital tools as scaffolding for learning*, includes the motivating effect of using the digital tools, but also highlights the benefits of using two applications with different approaches (phonics and comprehension-based) to meet the needs of all students in the classroom. However, sustaining motivation for educational applications was a challenge for the teachers, both due to the content and the distracting effect of other applications on the digital platform.

The third theme, *The impact of a supportive teaching environment*, brings together the teachers' thoughts about the importance of structure, both when it comes to the structure of the instruction occasion and the structure in the specific applications used in the intervention. The teachers themselves also highlight how they work to motivate the students and help them to generalise their new knowledge.

Finally, the fourth theme, *Student development*, focuses on the potential effects of the combined digital literacy interventions on the students' development in terms of literacy skills and communication. As students have varying conditions for development, this theme indicates that there is development when literacy skills are enhanced. However, the levels of development are different for different students, and some students need more time to assimilate new knowledge. The teachers also acknowledge that for some students, communication skills have shown a positive development during the intervention period.

IV INTERVENTION

The results showed that at the first test occasion, the Comprehension (beta = 2.19, 95% CI [0.61, 3.76], p = .006) and Combination (beta = 1.72, 95% CI [0.25, 3.19], p = .022) intervention groups had statistically significant better speech sound production compared to the Comparison group. The analysis further suggested that the Comparison group did not significantly improve in their speech sound production between the two testing occasions. The analysis of speech sound production after the literacy intervention indicated that all three literacy intervention groups (phonics-based, comprehension-based, and the combination of both approaches) had a positive effect of time that was stronger than for the Comparison group (Phonics *p* = .048, Comprehension *p* = .001 and Combination *p* = .027). The point estimates and confidence intervals suggested that Comprehension demonstrated the most pronounced effect.

There were missing data due to circumstances created by the COVID-19 pandemic, and five models for sensitivity analyses with imputed data were therefore conducted. The outcomes in these models were attenuated and showed a marginally significant positive effect of time (*p*s .05-.07) only for the Comprehension group compared to the Comparison group, and no effect of the other two interventions. Thus, the sensitivity analysis suggests that the results of the main analysis might not be robust.

DISCUSSION

The overall aim of this thesis was to examine the associations between speech production and literacy skills in students with ID and communication difficulties and to investigate the potential impact of a literacy intervention on speech production, from the perspectives of both teachers and students with ID and communication difficulties themselves and by comparing test data before and after intervention. The discussion will also focus on methodological issues that need to be considered to enable the inclusion of students with communicative and cognitive disabilities in intervention and research.

EARLY LITERACY SKILLS AND SPEECH SOUND PRODUCTION

Studies I *Associations*, III *Teachers' views*, and IV *Intervention* collectively supported the notion that speech sound production and early literacy skills are associated. Since reading is a linguistic activity, it has been presumed that when reading skills are stimulated, it potentially affects other linguistic areas. The theoretical model from Stackhouse and Wells (1997), in which phonological awareness constitutes a link between speech and literacy, supports these results, showing that there is also a link for students with ID. Therefore, a focused literacy intervention could have a positive impact on speech, language, and communication although further research is needed to determine the causal relationship.

The analysis in Study I *Associations*, revealed an association between early literacy skills and accuracy of speech production. Previous research of cerebral palsy (Peeters et al., 2009; Vandervelden & Siegel, 1999) and Down syndrome (Burgoyne et al., 2021) supports this association. The positive correlation between early literacy skills and speech sound production in Study I *Associations* also reaffirms the findings from research on the general population, suggesting that this association is not specific to the population with ID (Preston & Edwards, 2010). Interestingly, the results from the regression analysis showed that in this group of students, early literacy skills explained 26% of the variance, while chronological age and IQ together explained 3%. This implies that individuals with ID and communication difficulties, who possess stronger early literacy skills, are also more likely to exhibit enhanced speech sound production. Therefore, these results indicate that literacy intervention may positively affect speech production in line with

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theoretical models presented by, for example, Stackhouse and Wells (1997), Kolinsky et al., (2021) and Huettig and Pickering (2019).

In Study IV *Intervention*, the connection between literacy and speech was specifically investigated in the context of a literacy intervention for the participating students with ID and communication difficulties. The results indicated that for the full data set, literacy intervention, regardless of approach (phonics, comprehension-based, or a combination), had positive secondary effects on speech sound production. However, when checking for the robustness of our results in an analysis of imputed datasets, the significant effects of the interventions did not persist, although the effect of the comprehension-based application (Animega-is) approached statistical significance. Although conclusions were somewhat ambiguous after the sensitivity analyses, we nevertheless posit that for children with ID and communication difficulties, incorporating literacy intervention alongside other interventions may serve to enhance speech sound development. We still consider our positive findings to be noteworthy considering the small amount of previous research on the impact of literacy interventions on speech outcomes in this specific population and the overall trend in the results from this research. The results are also in line with clinical observations and other research studies on the population with ID suggesting positive results in speech development as a secondary effect of literacy interventions (Buckley & Bird, 1993; Light & McNaughton, 2019; van Bysterveldt et al., 2010).

In Study III *Teachers' views*, teachers also reported in the interviews that they perceived that many of the students who used both applications exhibited new knowledge and development. Despite the fact that the students were at an early reading level and the intervention lasted only 12 weeks, which is a short duration for this target group, the teachers reported that they could still discern a change. The development noted by the teachers ranged from an increased interest in reading and text to the acquisition of alphabetic decoding skills. According to the teachers, the students progressed in their development in terms of speech, language, communication, and literacy proficiency, but at different levels. The teachers reported that this development made the students proud of their achievements, and they were also, in several cases, unexpectedly receptive to the intervention, sometimes to the teachers' surprise. Regarding literacy development, the teachers' experiences reinforced the growing understanding that in terms of positive developments in literacy skills, instructing students with ID and communication difficulties poses a challenge, but is certainly not impossible (e.g., Ainsworth et al., 2016; Erickson &

Koppenhaver, 2020; Light & McNaughton, 2019; Light et al., 2008; Yorke et al., 2020).

In terms of communication development, the teachers noted a positive change for many students in several areas, primarily in the pragmatic and grammatical functions. However, the teachers did not note any significant improvements in specific speech sounds as described in Study IV *Intervention*. Alternatively, a more detailed analysis is needed to detect the subtle differences. Something that was evident in Study III *Teachers' views* was that the teachers had an important role in keeping the student motivated and providing a good interaction throughout the session, which potentially enhanced the results in the area of communication. Using recasts and providing a meaningful communicative context are important steps (Clarke et al., 2017; McTigue et al., 2020). Research on interaction and recasting demonstrates positive outcomes for both children with ID and mixed aetiology and ASD (Heimann et al., 1995; Tjus et al., 1998; Tjus et al., 2001). An important implication when creating both applications was that the interaction between the student and teacher is important and necessary for supportive instruction environment (Clarke et al., 2017; Light & McNaughton, 2019).

To gain a deeper understanding of the individuals and circumstances where literacy intervention could enhance speech production, it is essential to take various factors into account, especially when developing interventions to improve speech production in individuals with ID and communication difficulties. An effective approach should include an integrated and multidisciplinary strategy that considers the individual's strengths and weaknesses. This approach is likely the most effective way to enhance speech production and overall communication abilities, and we assert that it is particularly relevant in the current context.

LITERACY, COMMUNICATION, AND DIGITAL INTERVENTION FROM THE PERSPECTIVES OF STUDENTS AND THEIR TEACHERS

It is important to highlight the fact that listening to and respecting children's views is not only good pedagogical practice, it is also a legally binding obligation (United Nations Convention on the Right of the Child, 1989). The school setting is not an exception. Enabling individuals with ID to participate in research and have their voices heard, is something clinicians, educators, and

researchers must try to facilitate, even though it can be challenging in many cases. Considerable research has been conducted on various vulnerable groups with communication difficulties (for a review, see Stans et al., 2019), and the findings from Study II *Students' views*, have contributed to the ability to achieve inclusivity for students between 7 and 21 years with a range of ID from mild to severe.

Overall, many of the students in the DiLL project were able to respond to the questions regarding speech and reading activities with Talking Mats. They were able to answer the questions by placing the corresponding picture on the visual scale. The positive answers on speech activities, especially the two questions where participants spoke to only one person at a time and on the phone, may reflect the students' capacity for everyday communication. More often than not, this communication is with an adult rather than with peers in a group setting, even if the students have the opportunity to communicate with peers (Andzik et al., 2016; Chung et al., 2012; Raghavendra et al., 2012).

The lower percentage of positive views for reading activities, coupled with the increased complexity of tasks and the small positive correlations between students' views and their respective abilities, suggest that the students possessed some form of metacognitive ability to effectively express their experiences related to speech and reading activities with nuance. Reflecting on one's knowledge and skills can be an important part of development, as well as an integral aspect of one's identity. The students' positive perceptions of the applications (as reported by the teachers), signals the potential for personal growth and increased confidence in one's abilities. As confidence in learning to read grows, it also becomes more enjoyable, creating a positive spiral towards more reading (Stanovich, 2009).

For teachers and their students with ID and communication difficulties, involvement in research projects is not a common occurrence, making the teachers' perceptions of this literacy intervention project particularly important. The teachers may have insight into another qualitative side of the student's development that quantitative test data cannot show (Hara, 1995). It is also interesting to discuss the inclusion or, rather, the exclusion of individuals with ID in research. In much of the research on literacy intervention, students with ID are typically not included.

TOOLS FOR TEACHING LITERACY

Schools are obliged to provide communication and literacy instruction for students with ID, but challenges arise. The use of the two applications to teach literacy to this heterogenous target group was perceived by the teachers as both positive and challenging in Study III *Teacher's views*. Several positive aspects were highlighted, including the affirmation of teachers' competence through the materials provided by the applications, the functional and well-thought-out content that suited various levels, the structure provided by the applications, and the gradual increase in difficulty, which challenged the students without moving too quickly. The material used in special education needs to be adapted, and educators who work with the population need to have the patience to work with the student over a long period of time before seeing progress. The participating teachers in our study had a positive attitude toward digital technology and its potential to enhance literacy skills, similar to the perceptions of many other teachers in Sweden (Fälth & Selenius, 2022). The lack of instructional material for students with ID in the Swedish schools is apparent, which was also highlighted by the teachers in the interviews in Study III *Teachers' views*. Some teachers also reported uncertainty regarding their student's knowledge, skills, and ability when it comes to literacy. Many cited the lack of material, but also the lack of knowledge regarding how to evaluate these skills. The Swedish National Agency for Education (Skolverket) has developed a national assessment support tool for schools for students with ID, but this was not mentioned by the teachers. It is therefore important to conduct research using the available instructional material for teachers working in schools for students with ID, so that the country can meet these challenges and provide well adapted, evidence-based material, as well as useful assessment instruments.

When it comes to computer-assisted intervention for literacy acquisition, the teacher clearly has an important role, as shown in Study III *Teachers' views*. Research needs to further investigate to what extent the methods and applications themselves support learning in the students, and to what extent the teacher's ability to motivate and instruct students supports in computer-assisted literacy instruction (McTigue et al., 2020). Prior to this intervention, teachers participated in a digital workshop where the applications were demonstrated, and they had the opportunity to try them out under supervision. Continuous contact with the teachers allowed the research team to assess their progress, and teachers reached out when the applications did not function as expected. To enhance reliability in assessing the teachers' abilities,

observations could have been an effective additional measure during the intervention. However, the applications were perceived as relatively easy to manage and understand. This has allowed other school staff members to conduct teaching even when the teacher was not present. However, as the results in the review of research using Graphogame indicate (McTigue et al., 2020), the teacher is a crucial component in interventions, and is perhaps in many cases, the decisive factor for success in reading ability, with the tool itself being a facilitating component for instruction. Having materials that are easy to customize and can be used continuously as a student develops is an important factor, as it eases the burden of the teacher's everyday tasks.

Some teachers expressed that one challenge is that their students have difficulties generalising knowledge. Nevertheless, they observed that through persistence and repetition, many of the students made progress in both communication and literacy. This also highlights the importance of the teacher's role in incorporating the knowledge learned from the applications into real world situations in order to enhance generalisation. It is important to note that the teachers had their own notions of what the student knew before the intervention and what they knew afterward. Did the student already have more knowledge that the teacher had not acknowledged, or did the student acquire the knowledge during the intervention? However, Study IV *Intervention* aligns with these findings, suggesting a trend that supports the notion of communication development. The importance of conducting thorough and accurate assessments of reading skills in this target group has been stressed in prior research, both to determine the appropriate level of instruction and to evaluate acquired knowledge (Moats, 2009).

Also, as is often the case with digital tools, the assumption that the material is suitable for everyone was seen as a weakness, as some students lost interest faster than others. In such cases, teachers put in extra effort to motivate the students, for example, by offering rewards after lessons. Some students also found it bothersome when the content did not align with their own preconceptions, leading to frustration with the material. For instance, if the picture of a bee did not align with the students' own concept of a bee, the student could be unsure of the picture's meaning. However, even in some of those situations, the application stimulated conversations about the content.

METHODOLOGICAL CONSIDERATIONS AND LIMITATIONS

RECRUITMENT AND PARTICIPATION

Since most of the teachers volunteered to participate in the DiLL project, they were likely motivated to work with the applications in the intervention, which needs to be considered when generalising the findings.

Another methodological consideration about the recruitment of the students was that they were not recruited by the research team; instead, it was the teachers who performed the first step in the recruitment process. This introduces a potential bias, as teachers may have selected students who they believed to be most receptive to the intervention, and students may have been excluded for arbitrary reasons. The teachers did not report the number of potential participants that matched the inclusion criteria and how many they subsequently asked. However, in the beginning of the recruitment process, some teachers reported that they wanted to focus on fewer students. In conclusion, there remains uncertainty about whether the same students would have been included if the researchers had been responsible for the selection process from the beginning.

Caregivers also needed to provide consent, and we lack information on the number of caregivers who did not provide consent for their child's participation. However, many parents in the report from FUB (2023) reported that the literacy education provided to their child is inadequate. Based on this report and the fact that the literacy intervention took place during school hours and thus did not put an extra burden on caregivers, the refusals from the caregivers were likely low in number.

The teachers in Study III *Teachers' views* volunteered to participate in the subsequent interviews, which may indicate that they had a strong interest in sharing their experiences and that they had a positive view of the intervention to some degree. There is also a risk that the participating teachers portray an idealised narrative of their students' development, as they themselves would like to see progress and/or due to social desirability in relation to the interviewers. Although this may be true, the teachers' descriptions included nuance, since they also highlighted the difficulties their students faced in acquiring literacy skills, as well as the challenges of keeping the students' motivated during the intervention. Thus, listening and learning from the

students' perspectives is considered to be essential when conducting research on literacy learning and literacy instruction in this target group.

Recruitment was conducted in two waves, with the comparison group and phonics-based group completed first. This was because the interventions started at different time points, as the applications were not ready to be used simultaneously. Also, the implementation of the intervention involved a considerable administrative workload. This primarily had an impact on Study III *Teachers' views* and Study IV *Intervention*, where the groups were not fully balanced regarding IQ level and speech sound production. The comprehension-based group had more students with mild ID and none with severe ID and the distribution of additional diagnoses was uneven between the four groups. This could influence the result, especially in Study IV *Intervention*, as the speech sound production in different levels of ID and diagnoses may have different aetiology and potential to be affected. In Study I *Associations*, analyses were conducted to explore differences on speech sound production, phonological awareness and letter-sound knowledge based on various diagnoses, as well as sensory impairments; however, no statistical differences were found suggesting that this heterogeneity was not a very big problem.

The participants in this thesis had a wide age range (7-21 years). This meant that the students had different levels of experience with school-based educational settings, and the older students had likely been exposed to literacy instruction in their most recent years of schooling. However, the inclusion criteria were independent of age, and the results from Study I *Associations* indicate that chronological age did not significantly affect speech sound production for this group of students, nor did IQ.

The literacy intervention took place during the COVID-19 pandemic from January 2020 until June 2021. This affected the research in many ways, with the most significant effect being missing data, primarily in the post intervention test scored in Study IV *Intervention*. One schools were forced to close for a short period of time, thus delaying the data collection. Data collection for May of 2020 was particularly affected for the comparison group, where all assessments had to be pushed back one month. Many students and teachers were also in quarantine, even if they did not have confirmed COVID-19 themselves. The population in this thesis is a vulnerable group for infection (Courtenay & Perera, 2020) and because of that, some of the students were kept home for their own safety. As a result, some students were unable to

complete the intervention or participate in the final assessment, leading to missing data for those students. This may have influenced the outcome regarding the impact of literacy intervention. The sensitivity analyses with imputed data did not confirm unambiguously that the literacy intervention had the same level of effect on speech sound production as the analyses of the original data set suggested. Thus, further research is needed to explore the research question. Additionally, some of the assessments were also conducted with test administrator wearing facial shield or with a secure distance. We do not know to what extent this affected participants in our studies, but there are indications that the use of face masks can affect a child's capacity for phonological processing (Lalonde et al., 2022). This was an extraordinary time for the entire world, but Swedish schools for students with ID were an exception compared to other countries as they remained open (Buonsenso et al., 2021). This made it possible to continue the literacy intervention despite the effect of the pandemic.

ASSESSMENT OF THE ID POPULATION

Finding an adequate way to test skills in individuals with ID is a challenge. How do we know that we are assessing the skills and abilities we intend to assess? We may not only need to adapt the educational material the teachers use in a school setting, but also the test materials teachers, clinicians, and researchers use for assessment purposes. Furthermore, in addition to the need to adapt material, the instruction situation itself can present challenges for the researcher in terms of meeting the needs of individuals with ID, especially among students who require AAC. Research and other assessment tools need to allow students to demonstrate their knowledge in ways other than through speech.

Several considerations need to be made regarding the assessment of speech in our project. The speech sound assessment included all Swedish phonemes, but not all of them were represented in every position within a word in the assessment material. Also, the recommendation to elicit spontaneous speech (Shriberg & Austin, 1997; Shriberg & Kwiatkowski, 1982) was not possible for many of the students, as many of them were not able to participate in a longer conversation. Potentially, a test where only one picture is presented at a time could have been easier to use for these students than the action picture we employed, because there were a number of other items in the action picture in addition to the target words. Moreover, some participants were unable to spontaneously produce all the target words, but after prompting, either

semantically or through repetition, many more were able to complete the assessment. It is important to acknowledge that this prompting, especially through repetition, could impact pronunciation, as repetition may be more manageable than independent speech production (McLeod & Masso, 2019). However, the motor programme used for pronunciation still had to function. If repetition is better than naming the word, it indicates, according to the psycholinguistic approach, that the articulation skills are not the main problem. Instead, the difficulty lies in the production of the word from his/her own linguistic representation (Stackhouse & Wells, 1997). This can be caused by a deficit in phonological representation or an incomplete stored motor programme, or due to poor links between the semantic and phonological representation and /or motor programme (Stackhouse & Wells, 1997). Without the use of elicitation strategies, our assessment is that the students would have produced fewer words. Further, it is worth considering that this approach may have assessed not only the participants' speech sound production, but also their linguistic abilities, including vocabulary and word retrieval. The material from B.A.F. used in this thesis was not the complete test, which would be preferable in future research as it enables a more comprehensive analysis. Additionally, a more detailed overview of individual phonemes and the production of consonant clusters for each student were not possible in the context of this thesis.

The letter-sound knowledge assessment also had a smaller selection of the letters and sounds in the Swedish alphabet. It would have been preferable to have a wider representation of the different sounds, including more fricatives and nasal sounds. However, the decision was made not to include all items due to the large test battery that needed to be used and the importance of not overloading the students. Nonetheless, in future research, a more comprehensive assessment of letter-sound knowledge is recommended.

In this thesis, Study II *Students' views* aimed to include the students by asking them questions about different activities regarding speech and reading. The method Talking Mats can be an effective way to capture and develop the views of individuals who struggle with communication. The challenge with this method lies in formulating the questions in a way that can also be answered using the visual scale provided on the Talking Mat. The visual representation of the question is a valuable tool, but it is important to ensure that the participant understands the question. Using a practice mat before the interview is important for validating the participant's comprehension of the method, even though each question is new, and nuances always exist. In Study II *Students'*

views, it was observed that many students were able to use the practice mat and were consequently offered questions regarding reading and speech activities.

The questions used in the Talking Mats were framed as "What do you think about...?" and were answered on a three-point scale, building on the procedure for Talking Mats (Murphy & Cameron, 2008; Stans et al., 2019). Finlay and Lyons (2001) suggested that balanced scales should be employed with an equal number of positive and negative response options, along with a neutral choice. One disadvantage of using a three-point scale is that it can affect the accuracy of the measure and fail to capture the nuances and subtleties of participants' attitudes or behaviours (Hartley & MacLean Jr, 2006). Additionally, it may create a ceiling or floor effect, where the data becomes skewed towards the highest or lowest rating. On the other hand, there needs to be a good balance between alternatives with as much nuance as possible while also making it possible for the students to understand the structure and to participate (Boström et al., 2016). Thus, we still believe that the visual scale with three options was the optimal choice for most students who participated in the research in this thesis.

An individual's ability to express their personal views can be limited by factors beyond just communication and reading difficulties. The interaction between an interviewer and interviewee can be influenced not only by the misunderstanding of questions, but also by a tendency to give overly positive responses or a vulnerability to agree with others (Ellis, 2018; Finlay & Lyons, 2001, 2002; Matikka & Vesala, 1997). In a review of Hartley and MacLean Jr (2006) regarding the reliability and validity of Likert-type scales for people with ID, the findings indicated the presence of a positive response bias, with a higher likelihood observed in individuals with more severe levels of ID. The questions posed in Talking Mats were formulated in a way to avoid this positive bias. Just as Finlay and Lyons (2001) recommended, straightforward language, patience, and pictorial support were employed when using Talking Mats. When looking at the participants in this thesis, we found a potential positive response bias and vulnerability of acquiescence for 4.5% of the students since they were maximally positive on all questions. However, when looking more carefully at these five students, their answers were in fact highly aligned with their corresponding results on the tests. This may indicate genuine enjoyment of the reading and speech activities, thus reflecting to "true" positive ratings. Considering the full sample, the distribution of the ratings was more on the positive side (i.e. happy face) in both speech and reading activities, indicating a potential tendency towards positive responses.

HETEROGENEOUS POPULATION

The thesis included a large group of students with different diagnoses, which makes it a very heterogeneous sample. As for this study, this heterogeneity represents many of the school settings in Swedish schools for students with ID.

Even though comparisons between different subgroups with different diagnoses would potentially be interesting, the groups in this dataset are too small for statistical analysis with sufficient statistical power. As expected, it was also common for children to have several diagnoses simultaneously (Gillberg, 2010; Rensfeldt Flink et al., 2021), suggesting that even smaller subgroups would be needed to assess diagnosis specific patterns of results. Furthermore, many individuals with a diagnosis of ID have undiagnosed genetic and chromosomal syndromes (Vissers et al., 2016). Furthermore, ASD and other neurodevelopmental disorders are also likely to be underdiagnosed in children with cerebral palsy (Påhlman et al., 2021), Down syndrome (Reilly, 2009) and in children with more severe/profound levels of ID (Rensfeldt Flink et al., 2021). Therefore, it is recommended that future research investigates the extent to which specific diagnoses affect speech and literacy learning – and their interrelations – for students with various levels of ID and mixed aetiology.

The motor-function of speech was not specifically assessed in this study and is therefore something that could not be controlled for in the analyses. The results cannot be interpreted based on the different origins of the participant's speech deficits. At the same time, as described by Barry (1995) and Iuzzini-Seigel et al. (2022), the differential diagnostic process is difficult when it comes to phonology, childhood dysarthria, and childhood dyspraxia for populations with diagnoses where both cognition and motor and motor-planning may be affected. The fact that oral motor function (Mogren et al., 2020) and oral sensory perception (Aswathy et al., 2016) are not a part of the assessment in this thesis is a limitation that should be taken into consideration when viewing the results, especially in Study I *Associations* and Study IV *Intervention*. Here, information about the students' oral motor function could have provided a more precise picture of their speech capacities. Additional analyses were conducted in Study I *Associations* to investigate whether the different diagnoses influenced speech sound production, but the results did not indicate this. However, even within the same diagnosis such as cerebral palsy or Down syndrome, oral motor characteristics and abilities may differ substantially. Thus, future research is needed to explore factors such as speech-motor function and oral-sensory function in students with ID and communication

difficulties. At the same time, comorbidity with both phonological disorders and motor speech disorders is common in the study population (Alcock, 2006). In a clinical setting, it is important to also address the individual's need for treatment in relation to both oral-motor functions and cognitive aspects in language (Nijland et al., 2015; Shriberg et al., 2011).

A final potential limitation is that the teachers did not have the same number of students participating in the intervention. One could speculate that tutoring more than one student may have provided other insights, as working with more students could result in different experiences, such as a greater understanding of how the various applications work for different individuals.

CONCLUSION AND CLINICAL IMPLICATIONS

This thesis contributes to the limited body of research and knowledge about speech sound production and the associations with early literacy skills. All in all, the results show that early literacy skills and speech production are associated and that literacy intervention has the potential to positively impact speech production beyond reading ability for students with ID and communication difficulties. After the literacy intervention with either a phonics-based intervention, a comprehension-based intervention, and a combination of both for the students with ID and communication difficulties, it was found that all three intervention groups improved compared to the fourth group, which received teaching-as-usual. This implies that it is important to recognise the potential of literacy intervention to address literacy, language development, and communication. However, due to missing data, the results from the sensitivity analyses indicate that this causal interpretation needs further confirmation in future research.

According to the eight teachers who participated in Study IV *Intervention*, their students who received both phonics-based and comprehension-based interventions showed progress in the development of speech/communication and literacy skills. However, the development varied among students, with some improving in decoding skills while others progressed on a more communicative level. The focus on communication between the student and the teacher during an intervention may be a vital ingredient for success. More generally, the results highlighted the importance of structured and focused teacher support when the students worked with the digital applications.

This thesis also makes methodological contributions by showing that incorporating the student's perspectives, along with the teacher's perspectives, leads to important insights into the student's reading and speech capacities. Participating students expressed their views on speech and reading using the picture-based Talking Mats. The ratings for these activities also demonstrated a statistically significant correlation with the students' own speech and literacy skills. The clinical implications are that, with communication support, students can communicate their experiences related to speech and reading activities. This highlights the right of students to be heard, and that communication partners need to make adjustments to enable individuals to share their perspectives and provide the best possible support.

FUTURE PERSPECTIVES

It is important for future research to continue exploring the area of speech and literacy skills for students with ID and communication difficulties. Investigating various factors that influence speech development in connection with improved literacy skills is necessary. This includes paying attention to both mediating and moderating factors such as; vocabulary, working memory, phonological awareness, oral-sensory perception, attention, oral motor function, student-teacher interaction, and literacy and language exposure. Incorporating more details about these moderating and mediating factors could offer additional perspectives on speech and the potential benefits of literacy instruction as an intervention for speech sound production.

In order to see beyond an individual's difficulties and recognise the potential for growth is important for creating an inclusive research practice. Particularly, future research should place special emphasis on participant involvement and examine the possibilities of gathering participant opinions, especially among participants with ID. Future research may incorporate questions of a different nature by using Talking Mats and further explore the correlations between students' subjective perspectives and formal assessments.

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