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Reading instruction for students with intellectual disabilities who require augmentative and alternative communication: A multiple single case study with baseline, posttest, follow-up, and maintenance

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ABSTRACT

The purpose of the current study was to examine whether seven children, aged 6–10 years, with intellectual disabilities who require augmentative and alternative communication, could acquire phonological awareness and reading skills by using a reading material that is based on research on the evidence-based reading program Accessible literacy learning. The effect of the measures has been examined using a multiple single-case design with baseline, posttest, follow-up, and maintenance. All the teachers were trained to deliver the reading intervention in the students' familiar place at school. The results indicated that students with intellectual disabilities who require augmentative and alternative communication could acquire phonological awareness and decoding by working systematically with reading material based on evidence-based strategies.

What does this paper add?

This reading intervention for students with intellectual disabilities who require augmentative and alternative communication contribute to the debate on how to best support this group of students through systematic and explicit reading instructions to achieve functional reading skills.

1. *Introduction*

Literacy skills have a powerful impact on communication and language development, improvement of cognitive development, and advancement of learning for individuals with Intellectual disabilities (ID) and Autism spectrum Diagnosis (ASD) who require augmentative and alternative communication (AAC) (Light et al., 2008). Reading skills carry powerful benefits for individuals with complex communication needs. Once they can read and write, they can independently communicate any desired message. They no longer need to rely on others to provide them with pictures or graphic symbols to express their ideas (Caron et al., 2020; Lemons et al.,

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2016). Further, the ability to read and write can provide access to more linguistically advanced AAC systems (Romski et al., 2015). Nevertheless, the subgroup of students with ID who require AAC is underrepresented in reading research (Lemons et al., 2012).

Students with ID can face reading and writing acquisition challenges because of significant limitations to cognitive functioning and adaptive behavior (World Health Organization, 2023). Also, limitations in speech, language (Light & McNaughton, 2013), and phonological skills (Light & McNaughton, 2011;13; Næss, 2016) are skills that are commonly found in children with ID and are found to be associated with reading and writing acquisition (Sheldon & Erickson, 2020).

One reason why students with ID do not get the opportunity to participate in reading instruction or acquire reading skills is often a lack of evidence-based reading programs that are adapted to their needs. Most reading programs are designed for typically developed students who can use their speech functionally (Light & McNaughton, 2011). In addition, teachers' lack of expectations, experiences, and competence are deceptive factors for lack of reading instruction (Beukelman & Mirenda, 2013; Fenlon et al., 2010). Parents and teachers may have negative expectations concerning children with ID acquiring reading skills. This can affect the quality and time spent on reading-related activities, and it can indirectly affect the student's expectations for mastery and reduce motivation to learn to read (Light & McNaughton, 2011).

For students with ID, the focus has been chiefly on vocabulary development and the acquisition of high-frequency words (Browder et al., 2012; Spooner & Browder, 2015). However, high-frequency words are often not generalized and cannot be used functionally in academic or everyday contexts (Browder & Xin, 1998). Furthermore, high-frequency words in isolation do not contribute to students learning to decode unknown words, which can limit reading skills (Dessemontet et al., 2019). However, phonological awareness and letter-sound knowledge (Leppänen et al., 2008) strongly predict literacy development (Melby-Lervåg et al., 2012; Tunmer & Hoover, 2019). Browder et al. (2009) emphasized that students with ID benefited from teaching phonemic awareness. However, the phonemes needed to be visually presented in letters and pictures to respond without functional speech.

Children with ID and complex communication needs often face exclusion from phonological literacy approaches due to challenges in vocalizing speech sounds. However, research suggests positive outcomes when phonological interventions are adapted for AAC users (Barker et al., 2012; Dessemontet et al., 2019; Light & McNaughton, 2011, 2013; Yorke et al., 2021). It is recommended that teachers opt for evidence-based reading programs with explicit teaching, corrective feedback, scaffolding, rewards, repetitions, and systematic instruction in phonological awareness and phonetic skills, promoting skill generalization. Early integration of phonological awareness and letter-sound correspondence, along with direct instruction emphasizing modeling and guided practice, is crucial for effective learning (Browder et al., 2009; Lemons et al., 2016; Yorke et al., 2021).

2. *Existing research*

Research on reading interventions for students who require AAC mainly consists of a small group of single-subject-design studies that use different measures and teaching strategies and demonstrate varying degrees of success (Barker et al., 2012). This contributes to little empirical evidence, and it can be difficult to measure the effectiveness of these interventions, specifically designed to teach reading skills to children without verbal speech (Yorke et al., 2021). An increasing body of evidence emphasizes that many students with ID benefit from comprehensive, evidence-based literacy intervention (Allor et al., 2014; Connor et al., 2014). There are several studies confirming that this group can learn decoding skills by receiving intensive and systematic phonics instruction (Ahlgrim-Delzell et al., 2014; Allor et al., 2014). Allor et al. (2018) carried out a series of single case design studies with students with ID through three years. Results indicated consistent moderate-to-strong positive effects across all 18 participants for both sight words and decodable words, and across the eight decodable word studies.

Dessemontet et al. (2019) conducted a meta-analysis where two was experimental group studies (Ahlgrim-Delzell et al., 2016; Allor et al., 2010) (90 participants) and two was single-case studies (Lemons et al., 2015; Cohen et al., 2008) (10 participants). They found that these studies documented moderate to large effects. Yorke et al. (2021) examined interventions from 1980 to 2019 through a review that focused on improving phonological awareness (sound blending and segmentation), letter-sound correspondences, and decoding simple words. They investigated the effect of studies with designs adapted to the needs of individuals who used AAC. Seven of 22 interventions addressed Accessible Literacy Learning (ALL) (Ainsworth, 2014; Fenlon et al., 2010; Light et al., 2008; Millar et al., 2004; Wood, 2010; Westover, 2010; Yorke 2017). These studies showed an increase of 39 % in total and significant effects. Bakken et al. (2021) examined the effects of reading and writing interventions for students aged 4–19 with ID using randomized controlled trials (RCTs) and quasi-experimental designs (QEDs). The overall mean effect size from the reading interventions for trained reading was large. However, only one study, Ahlgrim-Delzell et al. (2016), specified that all the students were nonverbal and used AAC. Studies of Fallon et al. (2004) and Millar et al. (2004) were used to develop a literacy curriculum designed for children who use AAC (Light et al., 2008). The Accessible Literacy Learning curriculum (Light & McNaughton, 2011) includes the instructional strategies and materials demonstrated to be effective in these studies (Barker et al., 2012).

Yorke et al. (2021) emphasize that interventions should shift from being administered by researchers to other individuals working with the student, e.g., teachers, meaning effectiveness-studies rather than efficacy-studies should be prioritized. It is also recommended that teachers choose an evidence-based reading program based on explicit teaching, corrective feedback, rewards, scaffolding, repetitions, and carried out systematic instructions of phonological awareness and phonetic skills to maximum the students opportunities to generalize their skills (Lemons et al., 2016; Reichow et al., 2019).

Our study investigated whether students with different diagnoses, such as autism spectrum disorder (ASD), Down Syndrome (DS), and/or Cerebral Palsy (CP), and moderate ID as secondary diagnosis (age six to ten) who require AAC, could acquire early reading skills through instructions in phonological awareness (sound blending and phoneme segmentations), letter-sound correspondence, shared reading and decoding by working systematically and explicitly with the reading program "Lesing for alle" (Reading for all). The

adapted reading material has been designed based on the research of the evidence-based reading program Accessible Literacy Learning, ALL (Light & McNaughton, 2011). The current study adds to the evidence for the effectiveness of several early reading components for students with disabilities who require AAC.

The research questions were:

1) Is there a functional relationship between using "Reading for all" and increased accuracy of sound blending by minimally verbal students aged 6-10 with ID who require AAC?
2) Is there a functional relationship between using "Reading for all" and improved acquisition of letter-sound correspondence by minimally verbal students aged 6-10 with ID who require AAC?
3) Is there a functional relationship between using "Reading for all" and improved acquisition of phoneme segmentation by minimally verbal students aged 6-10 with ID who require AAC?
4) Is there a functional relationship between the use of "Reading for all" and improved acquisition of decoding by minimally verbal students aged 6-10 with ID who require AAC?

3. Method

3.1. Design

This study was conducted with a multiple single-case design with baseline, posttest, follow-up, and maintenance. We recruited nine minimally verbal students, aged six to ten, with different diagnoses, such as ASD, DS, and/or CP, and moderate ID as secondary diagnosis, who required AAC. Two students were withdrawn from the study for personal reasons right after the intervention started.

3.2. Intervention description

3.2.1. Study setting. The intervention took place within two special schools in Norway. The teachers, familiar with the students, delivered the instructions to the students during the school day. Each student had a special education teacher responsible for their educational training. All the teachers received individual training in test procedures, explicit teaching, and reading material. The principal researchers were available for questions and guidance throughout the intervention.

The training of the teachers started in September 2020. The students began with the baseline in September 2020 and worked for up to 24 weeks before the post-test. Post-test was carried out in March 2021. Follow-up was in June 2021, and maintenance in September 2021.

3.2.2. Recruitment. An information letter was sent to several special schools in Norway to recruit participants. The information letter gave information about the reading intervention, what it would mean for each participant to participate, the ethical assessments and privacy, and contained criteria for which students could participate in the study (see point 3.2.3, for inclusion criteria). It was the teachers who assessed which students were within the inclusion criteria, and the degree of verbal speech was described in the student`s diagnosis report. Verbal skills were not otherwise assessed. Teachers with students who met the requirements provided information letters and letters of consent to parents. Both parents and teachers had to sign a consent form. There were seven students and seven teachers who completed the intervention.

3.2.3. Participants. The criteria for being able to participate were that the students had to be between six and ten years old, not have a functional verbal speech (i.e. they had to use AAC as their main form of communication and use AAC to make themselves understood and to understand), not master more than 14 letter-sound correspondences, understand symbols, and be able to give answers in the form of pointing or eye control. They had been formally diagnosed with diagnoses, such as autism spectrum disorder (ASD), Down Syndrome (DS), and/or Cerebral Palsy (CP), and had moderate ID as a secondary diagnosis (i.e. IQ scores between 30 and 55). Exclusion criteria were students with either visual impairment, severe hearing impairment, or severe physical disability that would prevent the student from being able to point unless able to use eye-pointing or signs, and students who could decode single words and syllables. None of the students had a permanent place in a regular class, but their workplace was in a group room with two or three other students.

3.2.4. The reading material. The reading material "Reading for all" is based on the research on Accessible Literacy Learning, ALL, (Light & McNaughton, 2011). The material was designed with the software InPrint 3 with Widgit symbols (NorMedia, n/d). The material consists of three levels, with a gradually increasing progression. Through the reading material, the students encounter words/symbols mainly taken from the Norwegian version of the McArthur-Bates Communicative Development Inventory (also known as the CDI) (Kristoffersen & Simonsen, 2012). The words/symbols are taken from the CDI as it indicates receptive and expressive vocabulary from an early age (Kristoffersen et al., 2012).

Research indicates the CDI have good psychometric properties in for instance inter-rater reliability (Nordahl-Hansen et al., 2013) and concurrent validity (Nordahl-Hansen et al., 2014) for children with ASD. However, it should be noted that scores on the CDI can be sensitive to context (Pérez et al., 2020).

The material consists of phonological awareness components (sound blending and phoneme segmentation), letter-sound correspondence, shared reading, and decoding. All the instructional activities have been adapted, and oral/spoken responses are not

required for the students. The students can use alternative methods, such as signs, pointing at symbols, or pointing with their eyes. The reading material operates with six essential components:

Sound blending means that the students must combine sounds in spoken language into words, for example, the sounds /s/ /u/ /n/ to form the word "sun" (Lundetræ & Tønnessen, 2014).

Letter sound correspondence, i.e., linking the letters to corresponding sounds, knows the sounds each letter represents, and the letters used to describe different speech sounds (Light & McNaughton, 2011).

Phoneme segmentation, dividing a word into sounds, counting sounds, pronouncing each sound clearly and separately, and the ability to listen out and break down words into single sounds (Carnine et al., 2004).

Single-word decoding is the ability to recognize letters in words, associate them with correct sounds and pull them together to the word the letter sequence represents (Klinkenberg, 2015).

Shared reading, all students were introduced to shared reading activities through the reading material. The students were not tested in shared reading. Yorke et al. (2018) highlight the advantages of explicit teaching and shared reading because it favors language and vocabulary development and ordinary reading aloud is not as effective as explicit instruction in shared reading for students with ID (Browder et al., 2007).

3.2.5. Additional activities. It was also emphasized that the teachers had to work with additional activities such as flashcards and working on conceptual learning of the words they encountered in the reading program. All the teachers got flash cards and an overview of all the words that belong to the various levels in the material.

3.2.6. Design of the reading material. The tasks in sound blending, sound-letter correspondence, phoneme segmentation, and decoding are divided into four rectangular squares with a black A4 frame. There is a symbol, letter, or word in each square. There is a corresponding instruction on each back of the assignment. The instructions inform the teacher on what to say and how. The correct answer, target sound, or target word is marked in green so teachers can see the correct response. The instructions are short to adapt to the amount of verbal instruction the students can handle. Words and letters are written in small letters, with the font Arial, and the font size varies according to the different tasks. The "Shared reading" tasks are made with images from the ALL App (Tobii Dynavox, 2015). Through levels one, two, and three, students encountered many words and symbols, about 465.

The task sets consisted of 10 or 15 tasks, apart from shared reading, which in part one consisted of seven tasks, and nine tasks in part two. All the tasks were laminated to make the material more durable. The task sets were put into binders marked with numbers and letter names.

3.2.7. Material content

3.2.7.1. Direct and explicit instruction. **Level 0:** 1 folder (with about 60 tasks in explicit instruction in sound blending, letter-sound correspondence, shared reading, phoneme- segmentation, sight words, and single-word decoding). Explicit instruction involves the teacher identifying the skills for students to be taught in the lesson and then directly modeling the skill (Learning point Associates, 2004). The intervention used explicit instruction through progressive scaffolding, allowing for systematic concept modeling, guided practice, and independence.

The teachers followed the different scripts in the various reading components. During the first step, the teacher modeled for the student what was expected of them in each task.

During the second step, Guided Practice, the student was expected to be active in the lesson and was encouraged to point to the target item. In this step, the students get support to complete the tasks correctly together with the teacher. The teacher starts by saying, "let's do the task together". Same script as in the modeling phase, but the teacher encourages the student to do it together. During the final step, Independent Practice, students must perform independently. Teacher emphasizes and says:" Now it's your turn". The teacher points and confirms that the student has chosen the correct symbol. If the student answers incorrectly, the teacher corrects immediately.

Level 1: 8 folders (with about 120 tasks in sound blending, letter-sound correspondence and shared reading in each folder).

Level 2: 13 folders (with about 120 tasks in sound blending, letter-sound correspondence, phoneme- segmentation, single-word decoding, and shared reading in each folder).

Level 3: 11 folders (with about 150 tasks in sound blending, letter-sound correspondence, phoneme- segmentation, sight words, single-word decoding, advanced word decoding (for example, words with multiple consonant accumulations), not phonetic word pictures, recognition of high-frequency words and shared reading in each folder).

3.3. Assessments of the outcomes

It was a goal that the students should receive instructions daily for about 30 min. The teachers carried out all the work sessions, registrations, and tests. Several registration forms were developed to use during the data collection of outcomes. The forms used to record the daily work sessions and tests were designed so the teachers could tick off whether the students answered option one, two, three, or four. All the teachers registered correct or incorrect responses and percentage of correct answers during the assessments. During the intervention period, registration forms were collected, indicating how much the students worked, how much time they spent and how far they had progressed in the material. Only the teacher and student were present during the testing, and all the test situations were filmed. Within each phase, all the recorded films were evaluated by two of the authors for reliability purposes. Agreement between the two raters and the teachers were registered and calculated.

3.3.1. Outcomes. Outcomes were assessed at baseline, posttest, follow-up, and maintenance. The first and second author developed all the tests below (sound blending, letter-sound correspondence, phoneme segmentation and decoding). To the best of our knowledge there are no such available tests in Norwegian to assess students who use AAC with demonstrated evidence of validity. The assessments in this study focus on measuring phonological awareness, letter-sound correspondence and decoding, which align to the construct of the *Reading for all* program.

Sound blending [score ranging from 0 to 9] measured by adapted tests in line with the reading material "Reading for all". Testing in sound blending involves testing the student's ability to combine individual sounds into words. The students looked at a sheet of paper with four symbols. In the instructions, the target word was presented by expanding the individual sound in the word. For example: "sss-uuu-nnn". The students listened to the sounds, put them together in their head, and then pointed to the symbol that belonged to the word.

1) Letter-sound correspondence [score ranging from 0 to 25] measured by adapted tests in line with the reading material "Reading for all". Testing in letter-sound correspondence involved testing the student's ability to correspond between the sounds of speech (phonemes) and the written letters that represent speech (graphemes). The instructions asked the students to point, for example, at the letter sound "*a*". The student then had to discriminate between the target sound and three others.
2) Phoneme segmentation [score ranging from 0 to 9] measured by test in line with the reading material "Reading for all". Testing in phoneme segmentation tests the student's ability to segment the first phoneme of the word (e.g., *s* for *sun*). The students had to select the symbol for the word that began with the target phoneme and discriminated between four symbols.
3) Decoding [score ranging from 0 to 10] measured by adapted tests in line with the reading material "Reading for all". This test consists of 10 tasks with both CVC, VCC and CCV words, for example: bil (car), ost (cheese) and tre (tree). The students had to discriminate between four symbols where one symbol represents the target word and the other three consist of words with the same first sound, novel words, and similar forms.
4) Generalization test. An adapted reading test, OL 64, was carried out, which provides nuanced and systematic information about skills that are important for good reading and writing development (Nielsen et al., 2008). This assessed whether the skills could be generalized to other settings and materials and whether they read new words and had acquired phonological reading skills. The test was adapted by replacing the original drawings with Wigdit symbols (NorMedia, n/d).

3.4. Procedures

Before we started the intervention, we had to ensure that all teachers had the necessary materials, including a video camera with a memory card and a tripod. We also had to be sure that the teachers had necessary training in how to instruct, how to test and score and use the camera.

3.4.1. Research ethics and participant consent. The National Committee for Research Ethics in the Social Sciences and the Humanities (NESH`s, 2022) guidelines, and the Norwegian Agency for Shared Services in Education and Research (Sikt, n.d.) have been used as guidelines. Protection of participants in line with the International Committee of Medical Journal Editors (ICMJE, n.d.) was followed. Parents consented on behalf of their children. Information was given both in writing and orally.

3.4.2. Data management. Data was anonymized and stored on a restricted hard drive blinded *from peer review*, to which only the research team has access. Per the informed consent, anonymized data is retained permanently (except in the case of withdrawal during the study) and may be released to other researchers upon request. Identifying data (e.g., video films) will be deleted after four years. Data entry is completed and checked by the research staff. Physical anonymized data, which describes the weekly summaries from the teachers, is stored on a password protected laptop computer. Physical data is stored in locked cabinets and accessible only by the research team. The data controller was blinded *for peer review*, consented to the Data Management Plan.

3.4.3. What data was generated?. The data include the students' age, diagnosis, AAC, and results from the assessments and time used during the intervention. The data that appeared on each test listed the number of correct and incorrect responses, and from each work session the student forms also listed the correct and incorrect responses and the time used. It was essential to measure the students' work progress, because they had to achieve at least 80 % correct responses before they could move on to the following folder (Ulriksen et al., 2023).

3.4.4. Processing of data. Data processing and analyses was carried out in the programs Excel and the statistics program SPSS (Statistical Packages for the Social Sciences version 27). We recorded the recordings from the video observation in Excel. A form was designed for observability linked to each sub-skill. In the form, we recorded the numbers 0–4, where 0 = no response/difficult to see, 1 = response option 1, 2 = response option 2, etc. We plotted the results into SPSS and calculated the interobserver reliability using Cohen`s Kappa (Cohen, 1960).

3.4.5. Blinding. This is an open-label study because it is impossible to mask the students when the intervention started at baseline. The first and second authors coordinated the field work, and it was not possible to be blinded from the study subjects. Since all test situations across time were filmed after agreement and reliability checked by the first and second author, the teachers could not be blinded as to which phase of the intervention the students were at. However, the two assessors coded the outcome independently and

established interobserver agreement on the coded observations.

3.4.6. Interobserver reliability. All baseline and intervention procedures were implemented by the teachers. Interobserver reliability was done on 100 % of the video recordings by the first and second author separately.

3.5. Statistical analysis

We used linear generalized estimation equation (GEE), quasi-likelihood estimating processes (Zeger et al., 1988; Liang & Zeger, 1986), to estimate the rate of likely change on the four domains of reading development across the four time points being a frequentist method which can be used to analyze normal and non-normal longitudinal data (Liang & Zeger, 1986; Hanley et al., 2003). GEE has different types of working matrices and here we have the first order autoregressive effects, which assumes correlation between two observations decreases exponentially as the time between them increases. Given the reading development within childhood is a process that unfolds over time, and measurements collected from the same child at different time points are likely to be correlated. Taking account of the first-order autoregressive effects for this temporal dependency is crucial for accurately capturing the dynamic nature of developmental trajectories and increases the statistical efficiency of parameter estimation in longitudinal data analysis (e.g. rate of the improvement). Data were treated in long format and missingness are assumed missing at random mechanism and because GEE is a quasi-likelihood method, it does not require the complete specification of the likelihood function, which makes it robust to misspecification of the outcome distribution. It means that if we had at least one evaluation over time of the child over time, this child was considered in the estimation of the effect, an approach closely related to the intention-to-treat paradigm used in randomized trials to avoid missing participants when calculating effects. The adopted significance level of 0.0125 given the multiple outcome comparisons, avoiding the false discovery rates.

4. Results

Results in Table 1 describe the means and standard deviation across the four domains. It might be seen via the ordinary means change and increasing from baseline to follow-up, and then a decrease at maintenance.

The GEE showed that including the time as covariates improves the only-intercept model for all four outcomes and the rate of the increase across the reading skills (aka slope) can be seen at Table 2.

All four outcomes showed to be statistically significant (i.e., indicating an increase, on average, in the scores, on every assessment). For example, for letter sound there is an increase of 3.23 correct responses, on average, in each assessment Figs. 1–4.

There is high variation in the number of days and teaching time among the students. It must be pointed out that the reading intervention was carried out during the covid pandemic.

See appendix for descriptive statistics.

4.1. Interobserver agreement

Cohen's kappa was used to measure interobserver agreement. A Kappa of 0.80 and above is close to complete agreement, $>$ 0.61 is considerable agreement, and 0–0,4 is some agreement (Cohen, 1960). The calculations showed a Kappa of 0.81 and above, which indicated close to complete agreement. A deviation occurred at baseline in phoneme segmentation with a Kappa of 0.67, indicating considerable agreement. We had precise observation criteria in advance, so that both observers could score according to clear guidelines. For example, if the teachers gave wrong instructions such as "point at b" and used letter names instead of letter sounds, the observation criteria said that the student failed the answer. This also applied if the teachers gave several instructions or helped the students. The teachers were corrected if they gave the wrong instructions after the tests to ensure that they gave the right training in the reading intervention.

Table 1
Four domains of reading components across four timepoints.

Time		N	Min.	Max.	Mean	Std. deviation
Baseline	Letter sound	7	3	14	8,57	4117
	Sound blending	7	3	6	4,43	0976
	Decoding	7	0	3	1,29	1380
	Segmentation	7	0	6	2,57	2149
Posttest	Letter sound	7	9	22	17,00	5385
	Sound blending	7	3	9	7,29	2138
	Decoding	7	3	10	5,29	2289
	Segmentation	7	3	9	6,43	1988
Follow-up	Letter sound	5	9	25	20,20	6686
	Sound blending	5	5	9	7,80	1643
	Decoding	5	4	10	6,60	2408
	Segmentation	5	5	9	7,20	1643
Maintenances	Letter sound	7	8	25	18,29	5823
	Sound blending	7	6	9	7,71	1113
	Decoding	7	1	10	5,00	3266
	Segmentation	7	1	9	5,71	2984

Table 2
Rate of increase with time as covariate.

Outcome	B	Standard Error	Lower	Upper	P-value
Letter Sound	3.233	0.5570	2.147	4.324	< 0.001
Sound blending	1.053	0.1751	0.710	1.396	< 0.001
Decoding	1.202	0.4296	0.360	2.044	0.005
Segmentation	0.977	0.3844	0.224	1.731	0.011

Note. B = unstandardized coefficient regressions

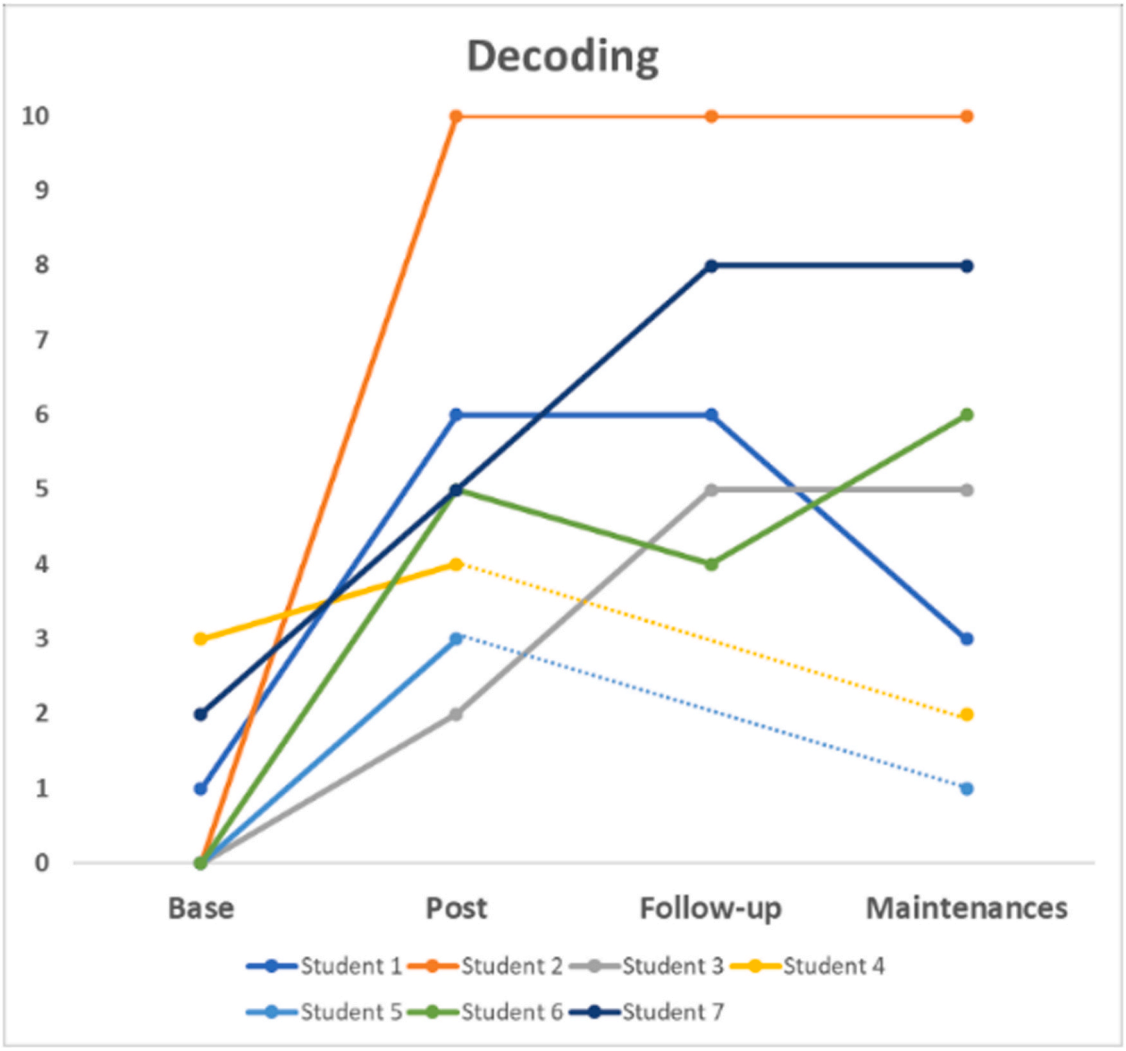

Fig. 1. Results in decoding for student 1–7.

5. *Discussion*

This study investigated the effects of the reading material "Reading for all" within the reading components: sound blending, letter-sound correspondence, phoneme segmentation, and decoding. The reading material was adapted and developed for students (ages 6 to 10) with moderate ID, who required AAC. None of the students in this study could decode simple syllables or words at the beginning of this intervention, and had varying skills in letter-sound correspondence, sound blending, and phoneme segmentation.

The answer to our research questions is that there is a clear functional relationship between the intervention and an increase in sound blending, letter-sound correspondence, phoneme segmentation, and decoding, especially for the students who worked steadily and continuously. Effects were more evident for sound blending, letter-sound correspondences, and phoneme segmentation than decoding. Probably, these students will need extended time to develop functional reading skills.

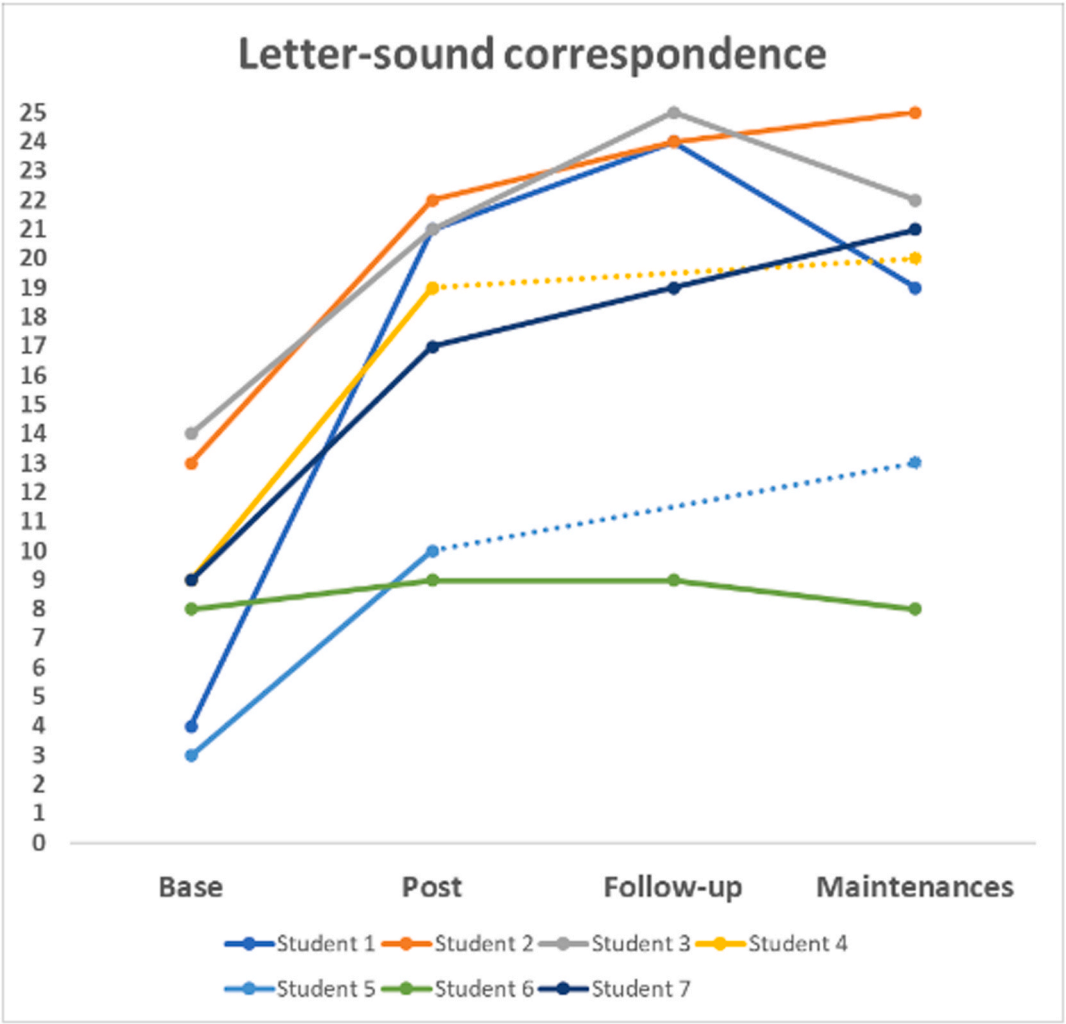

Fig. 2. Results in letter-sound correspondence for student 1–7.

Across the seven participants, the average dose of instructional time varied significantly between the participants. The lack of intensity of reading instruction was somehow expected because the intervention was carried out during the Covid period. The teachers also pointed out challenges related to absences, health, and other needs that had to be prioritized as factors for the difference in time of intervention the students received. Given the number of lessons missed from instruction, we saw that those who had the most teaching and worked continuously with the reading material showed the best results. We will assume that there is a disadvantage for this group of students to have a stay in teaching, and that it will affect the outcomes. Apart from the lack of teaching time, the intervention went as planned.

The very essence of the reading material is explicit and systematic teaching; modeling, scaffolding, and immediate and corrective feedback align with current research in the field (Lemons et al., 2016; Yorke et al., 2021). Working systematically with an explicit teaching folder contributed to the students acquiring a pre-understanding before they started with the tasks in the reading material. The teachers modeling, explaining, and showing may have led to an experience of mastery from the start. In the explicit teaching folders, the students received the necessary help within their zone of proximal development, they were praised for their efforts, and wrong answers were immediately corrected. We also consider the teachers implementing the intervention as a strength, and for most students it may be an advantage to be taught by a familiar teacher in a familiar place at school.

A strength of the material is the instruction for the teachers on the back of each task. Regardless of who taught the students, instructions were followed, and each lesson became predictable and recognizable to the students. This may have contributed to that the work sessions were carried out similarly, which we consider an advantage for this group of students. Further, the instructions written on the back of each task were short so that it would be possible for the students to process the instructions. Næss et al. (2017) point out that students with ID often need longer processing time to receive and process information and respond to instructions. Short and meaningful instructions are also important regarding working memory. Retaining information at the same time as processing the data can play a role when students read. If you have a weak working memory, remembering the first sound when you reach the last one can

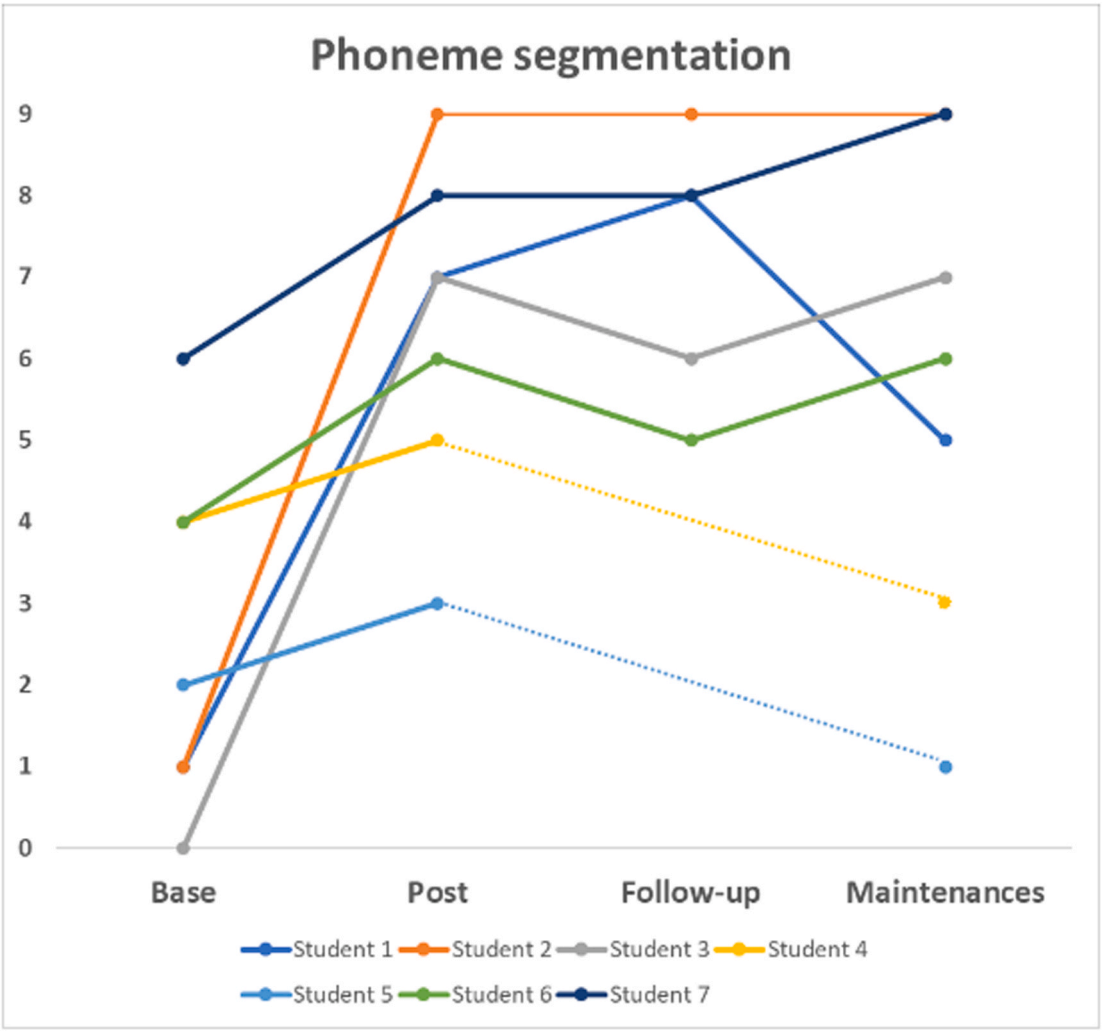

Fig. 3. Results in Phoneme segmentation for student 1–7.

be challenging.

Light and McNaughton (2013) claim that it is essential to record students' responses to ensure that teaching is as effective as possible. It was important to introduce good routines around registrations, as it gave a better overview of when the students had 80 % or more correct.

6. *Limitations*

The present study has several limitations. The tests in sound blending, sound-letter correspondence, phoneme segmentation, and decoding were researcher made and not standardized and normed. The teachers were also encouraged to teach the students to understand the meaning of words in the reading material, but this was not assessed.

The data collection was carried out by the teachers and scored by the teachers and two of the authors separately. Instructions on the back of each task and guidance ensured that the tests were carried out in the same way, and to prevent accidental measurement errors caused by the teachers. However, more specific instructions could have decreased measurement error. Although we used Widgit symbols in the reading material, which was familiar to the students, we should have mapped the student's understanding of symbols in advance. The students may have answered incorrectly because they had not mastered linking the target word to the correct symbol due to a lack of understanding of the symbols.

The practical implementation of the intervention could have had higher levels of control, other than the collection of registration sheets. The registrations provided information on how far the students had come and the time spent working in the intervention. The fact that we were not more involved in the intervention phase may be a weakness of the study. We should have observed implementation, as we saw the occurrence of wrong task instructions and varying time used by the students.

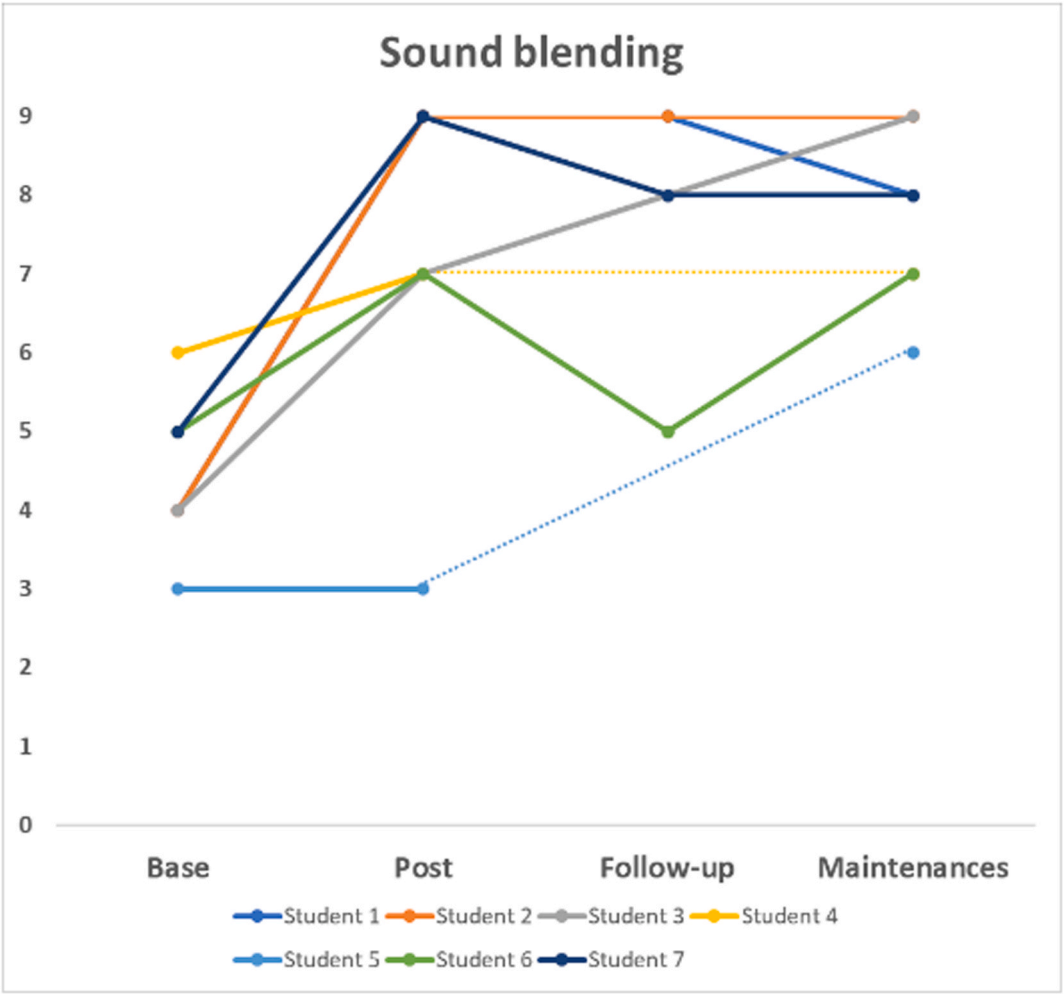

Fig. 4. Results in sound blending for student 1–7.

7. *Conclusion*

This reading intervention contributes to the current knowledge on the effects of reading instruction for students with ID who require AAC. The effectiveness of such reading programs depends on strategies and techniques known to be effective for these students.

Our results indicate that students with ID, without functional speech, who require AAC can acquire phonological awareness and reading skills by working systematically and explicitly with an adapted reading program. This aligns with current research in the field, which points out that this group of students can acquire functional reading skills (Ahlgrim-Delzell et al., 2014; de Chambrier et al., 2021; Lemons et al., 2015; Reichow et al., 2019). Given the importance of reading in improving opportunities and outcomes for students with ID and AAC and the challenges they experience in learning to read, we must improve our understanding of how to best teach students with ID who require AAC. According to Spooner & Browder (2015) it is perhaps the most important goal for every child to have the opportunity to learn to read regardless of IQ or diagnosis.

8. *Future implications for further research*

The effectiveness of phonic-based reading intervention programs adapted for students requiring AAC is lacking and needs to be investigated in future studies (Dessemontet et al., 2019). There is also a need for extensive randomized controlled trials across different contexts and groups of children in creating an empirically supported evidence base for reading instruction for students with ID who use AAC. The importance of valid assessments for individuals who require AAC is crucial. There is a strong need to develop standard phonological awareness and reading assessments for students with ID who require AAC. Future studies should also assess students' adaptive behavior to allow the reader to evaluate the severity of the participant's limitations more clearly and to know to which students their findings can be generalized (Dessemontet et al., 2019). To establish evidence-based practice for students with severe disabilities, several considerations are necessary, among other things, to explicitly state and define individual characteristics to ensure

replication, and that educators can select practices that will benefit their students with similar features (Spooner et al., 2017).

Ethics declarations

Ethical approval was granted via the Norwegian Agency for Shared Services in Education and Research (Sikt) on 24.08.20, Sikt registration form: 257203. Ethical approval has also been given by Østfold University College.

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CRediT authorship contribution statement

Line Britt Ulriksen: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Anders Johan Nordahl-Hansen:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Methodology, Formal analysis, Conceptualization. **Roald Øien:** Writing – review & editing, Writing – original draft, Validation. **Hugo Cogo Moreira:** Writing – review & editing, Writing – original draft, Validation, Methodology, Formal analysis. **Marthe Bilet-Mossige:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare no conflict of interest concerning the research, authorship, and publication of this article. The first and second authors have printed the material but have not made any profit from using the reading material in the study. Use of the Widgit symbols and images from Tobii Dynavox was clarified, and contractual, and they did not receive any royalties from this.

Data Availability

Data will be made available on request.

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