Facilitating Written Work Using Computer Word Processing and Word Prediction

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KEY WORDS
• fine motor skills
• school-based occupational therapy
• technology

OBJECTIVE. The purpose of this study was to investigate whether occupational therapy intervention that focused on teaching children to use word processing, either alone or with word prediction, was effective in improving the written communication skills of children with learning disabilities and handwriting problems.

METHOD. A single-subject alternating treatments design was replicated across three children in grades 4 and 5. During the baseline phase the children wrote stories by hand; during the intervention phase, the children wrote stories, alternating among handwriting, word processing, and word processing with word prediction. Dependent variables focused on percentages of legible words, percentages of correctly spelled words, total amount written, and rate of writing. Data were analyzed by visual inspection.

RESULTS. Results were variable. Two children had clear improvements in legibility when using either word processing alone or with word prediction. These same children demonstrated clear improvements in spelling when using word prediction. Though rate of writing was best for two children when using handwriting, relative to total amount produced, one method was not clearly preferable to another.

CONCLUSION. Occupational therapy intervention involving word processing with word prediction improves the legibility and spelling of written assignments completed by some children with learning disabilities and handwriting difficulties. It is important to evaluate each child individually and provide training and ongoing support for technology use.


The primary role of the school-aged child is that of the student. Within that role one of the key educational activities is the production of written work. Evidence suggests that, in elementary school classrooms, students spend an average of 43% of their day doing fine motor tasks and 85% of those tasks are paper and pencil activities (McHale & Cermak, 1992). Legible handwriting is necessary for children to carry out many academic activities (Amundson & Weil, 1996) and difficulties with handwriting can interfere with related writing processes such as planning and generating ideas (Graham, 1992). According to Benbow, Hanft, and Marsh (1992), “one of the most serious effects of poor handwriting occurs when the quality of handwriting detracts from the student’s ability to convey information and ideas” (p. 33).

Children with handwriting problems are frequently referred to occupational therapists (Benbow, 1995; Oliver, 1990). The focus for occupational therapy intervention with children who have handwriting difficulties is to assist the child in developing functional writing skills (Amundson & Weil, 1996). When the child’s handwriting is so poor that the child is unable to meet the demands for written communication in his or her educational setting, strategies that are able to offset the functional delay need to be considered (Amundson & Weil, 1996; Benbow, 1995; Johnson, 1996; Struck, 1996; Swinth & Anson, 1998).
Among the children referred to occupational therapists because of handwriting problems are students who have learning disabilities. Learning disabilities are characterized by deficits in learning that are related to academic achievement and may include problems in learning arithmetic, using oral or written language or both, and reading (Cermak & Henderson, 1985). Children with learning disabilities often have difficulty with writing assignments. These students frequently struggle with the mechanics of handwriting such as forming letters correctly and spacing words on the page (Cermak & Henderson), factors that are necessary to produce a legible final product (Amundson & Weil, 1996). The physical demands of writing are difficult, as are the complex processes of composing, organizing, and revising written work (MacArthur, 1996).

Word processing has many characteristics that make it a useful tool for addressing the needs of children who have occupational performance deficits related to poor handwriting skills and learning disabilities. Unlike handwriting, word processing ensures a neat finished product, allows editing without recopying, and facilitates collaborative writing projects (MacArthur, 1988; Mather & Roberts, 1995). It simplifies the production of text from manipulating a pencil in handwriting to pressing keys in keyboarding (MacArthur, 1988; Morocco & Neuman, 1986). Further, students tend to think that writing with a word processor is helpful (Lewis, Graves, Ashton, & Kieley, 1998; MacArthur & Graham, 1987) and tend to rate it more positively than writing by hand (Kurth, 1987).

Despite these advantages, studies on word processing for children with learning disabilities have shown mixed results. Several studies have shown no substantial difference overall between writing by hand and writing with a word processor (Collis, 1988; Dalton & Hannafin, 1987; Jacobi, 1986; Zhang, Brooks, Friel, & Redelfs, 1995). In a study that compared handwritten, dictated, and word processed stories, MacArthur and Graham (1987) found that dictated stories were longer and qualitatively better, but there were no significant differences between handwriting and word processing with regard to length, quality, story structure, mechanical and grammatical errors, and vocabulary used. The lack of a substantial difference between word processing and handwriting, however, may be due to the limitations of the studies. For example, a year-long study of 80 seventh-grade students that compared a holistic approach to teaching writing using a word processor to using the same teaching approach with handwriting showed no significant difference between the two methods (Dalton & Hannafin). However, writing samples compared in this study were all done using pen and paper regardless of the mode used during intervention. Therefore, the word processor may have been effective as a tool, although its effectiveness did not carry over when the children wrote by hand. In several other studies that found no difference between word processing and handwriting, the students' typing speed was slower than their handwriting speed (Collis, 1988; Dalton & Hannafin; MacArthur & Graham; Outhred, 1987).

Although these studies did not demonstrate word processing to be an effective tool for students in general, there is some evidence that using word processing can make a difference for some students. In one study of four students, the child who had the most difficulty with handwriting demonstrated the greatest gains when using a word processor (Jacobi, 1986). Dalton and Hannafin (1987) found that the 16 students in the word processing group who were identified as low achievers performed significantly better than their counterparts who wrote by hand. A study that compared the handwritten and word processed stories of 15 children with learning disabilities found that children whose handwritten stories were 50 words or less produced longer stories on the word processor (Outhred, 1987). In the same study, comparisons of misspellings revealed that the eight children who misspelled 30% or more of their words when writing by hand demonstrated a 6% to 17% decrease in spelling errors when using a word processor.

Another issue that has been addressed in the literature related to the effectiveness of word processing is keyboarding. Many of the studies focusing on word processing have failed to address the need to teach students keyboarding skills (e.g., Collis, 1988; Dalton & Hannafin, 1987; MacArthur & Graham, 1987; Outhred, 1987). This is concerning since MacArthur (1988) recommended that students be able “to use correct fingering while looking at the keyboard and to achieve a rate at least equal to their handwriting” (p. 538) in order for keyboarding to be helpful for students.

While teaching handwriting is an integral part of elementary school curricula, teaching word processing skills is not integrated into most classrooms. Using word processing requires mastering a variety of skills including managing files; keyboarding; and entering, formatting, and editing text (Cochran-Smith, Paris, & Kahn, 1991).

Computerized word-prediction programs have been developed to enhance the written communication of people with disabilities. Word prediction software uses rules regarding word frequency and grammar to provide the user with a list of words. As the user types the first letters of the desired word, a list of possible words appears on the screen and this list is revised until the desired word is predicted. Several authors reported that word prediction software can help support students with poor spelling skills or a poor
accomplishment in students with language and learning disabilities is quite important in maximizing the chances for academic success. According to Paul (1995), improving literate discourse “would seem to be quite important in maximizing the chances for academic accomplishment in students with language and learning disabilities” (p. 372).

The purpose of this study was to investigate whether occupational therapy intervention that focused on teaching children to use word processing and word prediction was effective in improving the written communication skills of children with learning disabilities. For this study, four specific questions were addressed. First, do these students produce written work that is more legible when using handwriting, word processing, or word processing with word prediction? Second, do these students produce written work that has fewer spelling errors when using handwriting, word processing, or word processing with word prediction? Third, which of the three text production methods allows these students to produce the greatest amount of written work? Finally, do these students produce work faster using handwriting, word processing, or word processing with word prediction?

Method

This study consisted of a single-subject, alternating treatments design (Kazdin, 1982) that was replicated with three children. It included a baseline phase in which children wrote by hand followed by an alternating treatments phase. During the latter phase, three conditions (handwriting, word processing, and word processing with word prediction) were alternated randomly. Between the baseline and alternating conditions phase, there was a training period that involved teaching the students keyboarding and basic word processing skills.

Participants

The study participants were identified by their occupational therapist, school psychologist, or special education teacher according to predetermined criteria including having a learning disability as defined by the State of Washington, WAC 392-172-126 (1997). Study procedures were approved by the Human Subjects Review Committee at the University of Washington and met the requirements of the large urban school district in the Pacific Northwest where the study took place.

A total of five students in grades 4 and 5 were identified for the study. Two students did not complete the training phase—one student moved out of the district and the other dropped out because he did not want to continue with keyboarding lessons. The remaining three students, Alice, Ryan, and Jason (pseudonyms) participated in the study. Alice was an 11-year-old girl with an IQ of 90 on the Wechsler Intelligence Scale for Children (Wechsler, 1991) and a diagnosis of “static encephalopathy.” She had her 12th birthday during the course of the study. Alice qualified as learning disabled in the area of written language and had occupational therapy goals that addressed handwriting difficulties including poor letter formation and inconsistent spacing between words. Ryan was a 10-year-old boy with an IQ of 98 on the Stanford-Binet Intelligence Scale (Thorndike, Hagen, & Sattler, 1986). He turned 11 during the course of the study. He had attention deficit disorder that was controlled with medication and qualified as learning disabled in the area of written language. At the time of the study, Ryan’s individualized education program included objectives related to punctuation, capitalization, and spelling. Ryan wrote using manuscript, interspersing upper and lower case indiscriminately. He rarely spaced between words. Jason was a 10-year-old boy with learning disabilities. He had an IQ of 101 on the Stanford-Binet Intelligence Scale (Thorndike et al., 1986) and qualified for special education services in the area of written language. In third grade, Jason began receiving direct occupational therapy services for fine motor skills that affected the legibility of his written work. He had severe spelling difficulties that also interfered with legibility. By the time Jason began participating in the study his handwriting had improved. He was consistently spacing between words and skipping a line.
when writing on wide-rulled notebook paper so that his words were better organized on the page.

**Instrumentation**

After consent was obtained, potential participants were screened to determine whether they had the ability to tell a story. The screening consisted of *The Bus Story: A Test of Continuous Speech* (Renfrew, 1991), a story retelling task in which children are told about an “naughty bus” that forms the basis of a narrative analysis. It was standardized on a sample of 573 children ages 3.5 to 8 years. For this test, a series of 12 pictures are shown to the child as the examiner tells the story from a prepared script. Immediately after hearing the story, the child is then asked to look at the pictures again and tell the story back to the examiner. The child’s story is scored based on the number of relevant pieces of information he or she included in the story. Norm-referenced Information Scores are provided. Renfrew reported stable test–retest reliability for Information Scores over 1- and 2-month intervals. All of the potential participants for this study met the inclusion criteria by scoring at or above the 7-year level on this test thus indicating that they all had the ability to generate narratives that included the basic elements of a story. This skill is present in typically developing children by age 5 years to age 7 years (Paul, 1995). Further supporting their verbal ability, all students scored at or above the 7-year level on the *Peabody Picture Vocabulary Test—Revised (PPVT-R)* (Dunn & Dunn, 1981), a standardized, norm-referenced test in which the student is asked to select pictures that best represent verbally presented vocabulary words. Test-retest reliability for this test ranged from .83 to .90 for students aged 10 and 11 years. In addition, it correlates well with other vocabulary tests (median value of .71).

This study required the use of a computer (8 megabytes of RAM, minimum) equipped with a word processing program and a word prediction program. Using the word processing program [Microsoft Word 5.0 (1991) or 5.1 (1992)], the students typed in text and made revisions by inserting and deleting text but did not use “Spell Check.” The “Word Count” feature was used to count the number of characters in the student writing samples. The selected font, Courier, has large spaces between words that are clearly visible on the computer screen.

When using the word prediction program, Co:Writer 1.1 (1994), the students selected words from a list of five words that were predicted “based on writing factors such as subject-verb agreement, grammar rules, user preferences, word relationships, and other factors” (Don Johnston Inc., 1999, p. 10). Co:Writer also automatically spaced after punctuation marks and selected words and capitalized the first word of every sentence. While several dictionary sizes are available, the 10,000 word dictionary was selected for this study because it predicted the highest percentage of words using the least number of keystrokes when the first author used Co:Writer to transcribe five sample essays written by fourth-grade writers of differing abilities. In addition, Co:Writer was set to collect new words as the student typed them. Speech and scanning options, abbreviation expansions, and in-line prediction options were not used.

**Procedures**

Prior to Phase One. Each student was asked to look through a packet of pictures and select 36 that he or she could write about. These pictures were randomly assigned to each session.

Phase One: Baseline. During the six baseline sessions, the students produced handwritten stories about their preselected pictures. Their rates of handwriting were determined by averaging their words per minute over the six sessions.

Training. Each student was prepared for the intervention phase by being individually trained in keyboarding, word processing, and word prediction. UltraKey 3.0 (1995), a computer keyboarding software program, was used for keyboarding skills training. UltraKey teaches all of the letter keys in 10 lessons. Speed and accuracy data are collected in skill tests associated with each lesson. The students completed their first three keyboarding sessions under the supervision of the first author. After that, students were asked to spend 10 to 15 minutes every school day working independently on the remaining keyboarding lessons and skill tests. Their progress was checked weekly by the first author. Two of the three students volunteered to do their keyboarding lessons during one of their recess times. The training was successfully completed after the students finished 10 lessons in UltraKey with at least 95% accuracy while typing at a rate that was within two words per minute of their rate of handwriting on two of three skill tests. The students’ rates of handwriting were the average words per minute calculated during the baseline phase of the study. In this study, the amount of practice needed to achieve functional keyboarding skills ranged from approximately 5 hours for Ryan to 17 hours for Alice.

Training in the use of the word processing software (Microsoft Word) and word prediction software [Co:Writer 1.1 (1994)] began after the first three keyboarding sessions were completed and continued until the students passed competency tests relating to operations the students would need to perform to compose and edit a story (e.g., adding text, deleting text, and saving their work).

Phase Two: Intervention. The students were asked to write stories about their preselected pictures using the three
text production methods (handwriting, word processing, and word processing with word prediction). A random numbers table was used to assign handwriting, word processing, or word processing with word prediction to each session in order to control for sequential confounding (Barlow & Hersen, 1984). A decision was made to randomly assign the text production methods within blocks of six sessions because the total number of intervention sessions could not be determined prior to the study. Random assignment without replacement was used so that each text production method was used twice during each block of six sessions. The intervention sessions were no more than 15 minutes long and were scheduled approximately three times per week. One student completed four 6-session blocks, one completed three 6-session blocks, and one completed two 6-session blocks.

**Data Collection**

The students’ stories were analyzed for legibility and spelling using a standardized method for objectively scoring student writing (Hasbrouck, Tindal, & Parker, 1994). Data were also collected regarding the amount of text produced and the rate of text production.

**Legibility of Text.** Legibility was defined as the percentage of text that was legible and was determined by dividing the number of legible words by the number of words written. Words were viewed out of context by beginning with the last word in the text and reading backward, one word at a time, while masking the surrounding words (Hasbrouck et al., 1994). Words that could not be correctly identified out of context (due to factors such as poor spelling and/or poor letter formation) were considered illegible (Hasbrouck et al.). This rule was applied to both handwritten and computer generated stories. Homonyms were considered legible but misspelled. Lack of spacing between words was not considered when determining legibility because the scoring method did not require “words” to be separated by spaces.

**Spelling Errors.** This was defined as the percentage of words that were correctly spelled. Correctly spelled words were counted and the total number of correctly spelled words was divided by the total number of words written.

**Total Amount Written.** This was defined as the total number of words produced and was determined by dividing the number of characters written by 5. A character was defined as a letter, number, punctuation mark, symbol, or space. Work that had been deleted or erased from the story was not counted. This formula was used because it allowed accurate comparison between stories regardless of the length of the words used. In addition, UltraKey 3.0 (1995), Microsoft Word 5.0 (1991) and Microsoft Word 5.1 (1992) defined one word as five keystrokes for their words per minute or word count calculations.

**Rate of Writing.** Rate was defined as the average number of words written per minute and was determined by using a stopwatch to time the student’s writing session. The number of words per minute (wpm) was then calculated as follows:

\[
\text{wpm} = \frac{\text{number of characters written}}{5} \times \frac{1}{\text{time to complete the story (in minutes)}}
\]

**Reliability.** Prior to the intervention phase of the study, a second rater was trained in evaluating student writing until the level of interrater agreement was at least 80% on all parameters. The second rater evaluated randomly selected stories for each student. Agreement was checked for two stories from the baseline phase and one-third of the stories from the intervention phase. A frequency ratio ([smaller total ÷ larger total] x 100) was used to determine percent agreement between raters for each randomly selected story. Average interrater agreements for the student stories written during the baseline (BL) and intervention (I) phases were as follows: legible words (BL = 95%, I = 96%); correctly spelled words (BL = 94%, I = 97%); and total words (BL = 100%, I = 99%).

To insure the use of standard procedures within and across conditions, procedural reliability checklists (Billingsley, White, & Munson, 1980) that delineated equipment set-up, the amount and type of reinforcement, and when cues could be provided were developed for each text generation method. The checklists were used at each session and reliability was determined by dividing the number of steps followed correctly by the total number of steps on the checklist. An observer checked procedural reliability at 18% of the sessions. Overall procedural reliability scores remained at 100% during the baseline phases and ranged from 96% to 100% (average = 99.6%) during the intervention phases.

**Analysis.** All data were graphed and inspected visually for differences in levels and trends between conditions (Kazdin, 1982). Data were compared to determine whether there was separation between the datum points for the three conditions (Barlow & Hersen, 1984).

**Results**

Figures 1 through 4 present the results obtained for each subject on each parameter. The intervention phase for Ryan started at the end of a school year. Computer and keyboarding skills were reviewed in the fall of the following school year. Ryan was retested to confirm that his skills remained at the appropriate level and data collection
Figure 1. Percentages of Legible Words.
Figure 2. Percentages of Correctly Spelled Words.
Figure 3. Total Amount Written.
Figure 4. Rate of Writing.
recommended in November with session 16. The extended
time period between sessions 15 and 16 is represented by
the double lines.

As indicated in Figure 1, Jason and Ryan showed some
improvement in legibility when using word processing as
compared to handwriting. However, they demonstrated the
highest percentages of legible words when using word pre-
diction (see Figure 1). Both boys also demonstrated clear
improvements in spelling when using word prediction with
no overlap between datum points for word prediction and
the other two conditions (see Figure 2). The method of text
production did not appear to effect the total amount writ-

ten for any of the students although on one occasion Ryan
completed a handwritten story that was much longer that
his other stories (see Figure 3). He explained his zeal for
writing that day as being due to the fact that he had for-
gotten his lunch and was very hungry. As shown in Figure
4, Alice and Jason demonstrated a faster rate of text pro-
duction when writing by hand with no overlap between
those datum points and the other methods, whereas Ryan’s
rate of writing using word processing was as fast or faster
than his handwriting.

The results of this study suggest that using word pro-
cessing and word prediction helped improve the quality of
writing for two students by increasing legibility and reduc-
ing spelling errors. During the intervention phase, 1 in 8 of
Jason’s handwritten words was illegible and he made
spelling errors in about 1 in every 4 words. When he used
word processing, only 1 in 17 words overall was illegible,
and approximately 1 in 6 words was misspelled. However,
when he used word prediction, 100% of his words were leg-
ible and, for the last two word prediction sessions, 100% of
his words were also correctly spelled. Ryan also showed
improvements in legibility and spelling. His frequency of
illegible words changed from 1 in about 11 words during
the intervention phase for handwriting to 1 in 24 words
overall for word processing and less than 1 in 100 words
overall for word prediction. Ryan’s frequency of spelling
errors changed from more than 1 in 8 words for handwriting
and word processing to fewer than 1 in 40 words for
word prediction. In addition, because Ryan rarely spaced
between words when writing by hand and spaced consist-
tently when using word processing, his word processed sto-
ries were considerably easier to read. This difference was not
reflected in the data because this aspect of legibility was not
measured.

Discussion

By fourth grade, students are expected to write clearly and
effectively, producing a legible final project that can be
shared with others (Washington State Commission on
Student Learning, 1998). Improvements in spelling and
legibility could have a dramatic effect on students’ grades
since low scores tend to be given when there are frequent
errors that make the writing difficult to read (Washington
State Commission on Student Learning, 1999). In this
study, the quality of writing for two students showed
improvements in legibility and spelling when they used
word processing with word prediction. This is congruent
with findings in the literature that have suggested that using
word processing or word prediction or both can make a dif-
ference for some students (Dalton & Hannafin, 1987;
Jacobi, 1986; Laine & Follansbee, 1994; MacArthur, 1998;
Outhred, 1987). In addition, the experiences associated
with this study have provided supplementary information
about what types of support provided by the educational
team are important for students to be successful with the
technology. Those supports include time for keyboarding
practice, a classroom environment that is technology-
friendly, and instruction in how to use the technology
effectively.

The ability to keyboard at a rate that is comparable to
the rate of handwriting has been recommended as a prereq-
uit for successful use of the word processor (MacArthur,
1988). This study followed that recommendation by pro-
viding keyboarding training and requiring a level of key-
boarding competence. Throughout the study, keyboarding
training seemed to be most successful when the students
practiced at least four times per week. This suggests that an
educational team recommending word processing technol-
ogy for a student needs to be prepared to devote time on a
daily basis for the student to successfully develop this skill.
Of the three students, only one (Ryan) was able to maintain
a rate of keyboarding that was comparable to his rate of
handwriting.

The variability in the classroom environments may
have influenced the students’ success in using the word pro-
cessing technology. The two students who showed im-
provements when using the computer (Jason and Ryan) had a
classroom teacher who was comfortable with technology.
He had multiple computers available for students, encour-
aged all students to use the computer for written reports,
and allowed Ryan and Jason to practice keyboarding during
class time. Alice’s teacher, however, said she knew very little
about the computer and her use of the classroom computer
was limited to some educational games and computer-
ized reading testing.

Teaching the students how to use the word processing
and word prediction software was an important aspect of
this study. Although only basic text entry and editing skills
were taught, Ryan and Jason individually developed the
same strategy for using word prediction to find the words they wanted. Their strategy involved trying different spellings until the desired word appeared in the predicted word list. This strategy dramatically improved the spelling of both boys. It also improved the legibility of Jason’s writing because his poor spelling made many of his words illegible (e.g., “wack” for “watch”). Thus, when he was able to improve his spelling using word prediction, the legibility of his work also improved. Teaching this strategy directly might increase the effectiveness of the word prediction technology for other students.

Finally, this study, which was relatively easy to implement within the school setting, provides a model and step-by-step process for evaluating the effectiveness of occupational therapy interventions. First the intervention technique and specific objective criteria for measuring change were identified, consistent procedures for collecting data were defined, and a baseline was obtained. This process is consistent with the planning that is done annually as part of a student’s individualized education program. Once the intervention plan was implemented, data were collected frequently, charted, and compared. Although scoring was time consuming because data were collected on many aspects of student writing (legibility, spelling, rate, and quantity), a simpler version that focused on one or two outcome variables could be quite workable. The need for changes in the intervention (i.e., additional training, integrating the program into the classroom, etc.) could be identified, justified, and implemented based on the findings.

Limitations and Directions for Future Research

One important limitation of this study is the possibility of one intervention affecting another. For example, using word prediction software may have helped students to improve their spelling. This improvement may in turn have affected the students’ performance in spelling when using handwriting and word processing. In addition, while legibility can be influenced by many factors, only a narrow definition of legibility was used for this study. Another limitation was the use of pictures as story starters. Although the students chose pictures that sparked their interest, the static nature of the pictures may not have provided enough information to inspire the students to write longer, more dynamic stories.

Further research needs to be conducted in order to gain a better understanding of the benefits and limitations of word processing and word prediction technology as they relate to supporting the student throughout the writing process. This study examined the rate of student writing related to the completion of a short first draft rather than the completion of a final draft. When the process of editing and revising is taken into account, the use of the computer may speed up the writing process by eliminating the time required to copy handwritten work. Although using word processing technology slowed the rate of writing for two of the students in this study, it did not have a clear impact on the total amount written. Since the students tended to write a comparable amount regardless of the method used, word prediction may be more time efficient than handwriting in the long run because there are fewer errors to correct and no need to recopy the entire document. In addition, the rate of handwriting might have decreased significantly if the students had been asked to do their best work while the rate of writing using word prediction might have increased if there were more opportunities for the students to practice this skill.

To help occupational therapists facilitate the successful integration of word processing technology into classroom programs, further research is needed in the area of keyboarding instruction. Research could help to determine how much and what type of practice is needed for students to develop, maintain, or increase keyboarding skills or both.

Conclusion

The results of this study suggest that occupational therapy intervention involving word processing and word processing with word prediction can facilitate written work by improving legibility and spelling for some students with learning disabilities. Although the rate of writing was best for two students when using handwriting, there was no clear impact on the total amount written. The success of the technology varied depending on each child’s unique needs, talents, and environmental supports. This suggests that a careful evaluation of each individual child’s occupational performance deficits should be conducted prior to making recommendations regarding this type of technology. In addition, a commitment by the child’s multidisciplinary team is needed in order to provide the training and ongoing support necessary for the child to successfully use such technology.

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