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The Effectiveness of SOLO ™ on the Writing Outcomes of Students with Learning and Academic Disabilities

Final Report to the
National Center on Technology Innovation

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ABSTRACT

This project investigated the educational outcomes of the use of SOLO™ from Don Johnston Incorporated (DJI) as a support to interventions designed to increase the writing skills of students with learning and academic disabilities. Teachers of students with mild disabilities (learning and behavior disabilities) at each of three levels (intermediate elementary, middle school, and high school) who had previously received training in the use of portable keyboarding devices, voice output, word prediction and/or text-to-speech reading software received training in the use of the integrated SOLO software. These teachers also received instruction in the use of a systematic set of writing outcome measures. Finally, these teachers participated in a SOLO User's Group (UG) facilitated by staff of the SEAT Center at Illinois State University (ISU) to support integration of the software into writing activities and use of systematic outcome measures. The outcome measures provided for classroom-based evaluation of the effects of assistive technology (AT) on students' abilities to complete key aspects of the writing process. Writing outcome measures include attitude toward writing; written productivity, mechanics, accuracy and complexity. Forty three students with learning or academic disabilities participated in the study. The effectiveness of the AT product was evaluated using a quasi-experimental Concurrent Time Series Measurement design, in which specific writing samples were collected both with and without the support of the AT (concurrent measures) and with sampling repeated over time (time series). Each of the student served as his/her own control with comparisons of AT-supported and non-supported writing being examined over time. Preliminary results indicated that both standard and AT produced higher rates of word production and lower spelling error rates with AT producing the largest and most consistent reductions in spelling errors on second drafts. Elementary grade students benefited the most from the AT in reducing both first and second draft spelling errors. Elementary and middle schools students produced the lowest punctuation and capitalization errors using assistive technology; standard technology produced fewer errors than no tech (handwriting) but not as few as AT. High school students made few capitalization and punctuation errors using both standard and AT. Using the AT, students across all levels produced the lowest number of inaccurate sentences (fragments, run-ons and grammatically incorrect) and wrote longer grammatically correct sentences during first draft writing. Sentence length was used in this study as a proxy measure of sentence complexity, thus results indicated that students increased sentence complexity in their writing samples when using AT even during first drafts. Reliability analyses of the teacher-scored writing samples is currently underway as is partial rescoring of some student data sets which were excluded from this preliminary analysis. Individual analyses of which components of AT (e.g., word prediction) were used and their effects on writing outcomes are still to be completed.

BACKGROUND OF THE PROBLEM

Congress acknowledged the importance of educating children with special needs with the passage of the *Individuals with Disabilities Education Act Amendments of 1997* (IDEA '97, PL 105-17). Whereas the focus of special education laws in past years was on assuring that all students with disabilities had access to a free and appropriate education, today there is far more emphasis on the quality of special education services. The *No Child Left Behind Act* (NCLB, PL 107-110) specifically lists students with disabilities as a "designated student group" that must be included in statewide and district-wide assessments that are aligned with high academic

standards. Recent attention has focused on student educational outcomes, in general, and in AT outcomes, specifically. The NCLB legislation has resulted in a strong focus on determining the academic and educational progress of all students. Standards-based reform in K-12 education (cf. McDonnell, McLaughlin, & Morison, 1997; (Thurlow, 2000) has focused attention on evaluating educational outcomes by examining (a) goals, (b) indicators of success, (c) measures of progress, (d) reporting, and (e) consequences (Thurlow, 2000). The IDEA '97 also demonstrates increased attention to the progress of students who receive special education services in the general education curriculum. Today there are higher expectations for students with disabilities than in the past, and best practice in educating these students has fundamentally changed due to the advent of new technologies. It is estimated that there are currently over 27,000 devices manufactured by over 2,000 different companies that have been specifically designed to enhance the learning and life functioning of persons with disabilities.

In parallel with these developments has been the mandate within IDEA '97 to consider AT when developing the IEP of any student who receives special education services. While earlier legislation [Individuals with Disabilities Education Act of 1990 (IDEA)] mandated that AT *should* be considered, the reauthorization (IDEA '97) required that AT *must* be considered for use with an estimated 6.2 million students ages 6-21 with disabilities. Subsequently, much attention has been focused upon the processes and procedures by which such consideration would be accomplished (Watts & O'Brian, 2002; Watts, O'Brian, & Wojcik, 2004). But, appropriately, "considering" and providing AT to the student is not, in itself, an acceptable outcome. Emphasis has shifted to determining and measuring outcomes related to AT (Edyburn, 2002) and has resulted in the funding of two five-year research centers by the National Institute on Disability and Rehabilitation Research to address AT measurement outcomes, instruments and strategies (("Assistive Technology Outcomes Measurement System," 2003; "Consortium on Assistive Technology Outcomes Research," n.d.). The goal of NCLB to require all students including those with disabilities to be proficient in basic academic content by the 2013-2014, either through standardized testing or alternate assessment (Waterman, 2004) greatly amplifies the need to determine whether the ever-increasing amount of the budget spent on instructional and assistive technology has an impact on student achievement (Edyburn, 2002). The question is no longer, "Have we considered AT?" but rather the question is now, "How has technology affected student performance?" (Barnett, 2000).

Literacy is a fundamental access point to the general education curriculum. Reading and writing are used throughout the curriculum across the grade levels as tools for acquiring and using information. Writing, in particular, is used for expressing what the student knows and can do in the content areas (English, Math, Science, Social Studies) and as a means of written expression encompassing a variety of genres and purposes (e.g., expository, persuasive, narrative, etc.). The problems of students with learning and academic disabilities in engaging in the writing process are well documented (Channon, 2005) as are a body of systematic strategies for providing instruction and intervention in the writing process ((Englert & Raphael, 1989; Englert, Wu, & Zhao, 2005; Graham & Harris, 2005; Graham, Harris, & Larsen, 2001; Graham, Harris, & Troia, 2000; Harris & Graham, 1996; Raphael & Englert, 1990). Over the last 10 years, research has demonstrated that computer-based tools such as keyboarding (Koorland, Edwards, & Doak, 1996), word processors (Lewis, Ashton, Haapa, Kieley, & Fielden, 1999; MacArthur, Ferretti, Okolo, & Cavalier, 2001; MacArthur, Graham, Schwartz, & Schafer, 1995)), and spell checkers (Dalton, Winbury, & Cobb-Morroco, 1990; McNaughton, 1997; Montgomery, Karlan, &

Coutinho, 2001) can be used within process-based writing interventions to increase quantity and quality of the written work of students with learning and academic disabilities (MacArthur, 2000 (MacArthur, 2000; MacArthur et al., 2001)). More recently, research has begun to emerge on the use of specifically designed AT to support writing interventions with these students, including prewriting organization software (Sturm & Rankin-Erickson, 2002), speech output word processors (Williams, 2002), word prediction software (Tumlin (Hunt-Berg & Rankin, 1994; MacArthur, 1999; Tumlin & Heller, 2004; Williams, 2002) and voice recognition (De La Paz, 1999; Faris-Cole & Lewis, 2001; Forgrave, 2002; Higgins & Raskind, 2004; Roberts & Stodden, 2005). While individually, these studies cover a range of grades, outcomes in the writing process, and types of writing support technologies, studies that use a comprehensive set of outcome measures combined with a systematic evaluation "design" across grade levels and a systematic "toolbox" of AT are needed to determine "how technology affects student performance."

METHOD

The Technology

This project investigated the educational outcomes of the use of SOLO™ from Don Johnston Incorporated (DJI) as a support to writing interventions designed to increase access to the general education curriculum with students with learning and academic disabilities. SOLO™ combines all the proven, industry-standard interventions from DJI—Co:Writer®, Draft:Builder®, and Write:OutLoud®—and introduces Read:OutLoud™ and offers one completely integrated solution to differentiate instruction and assist in the learning process. SOLO™ is designed to assist teachers present grade-level curriculum to students of differing abilities with guided support for reading comprehension, on demand topic-specific vocabulary and structured models for writing. Components of the SOLO™ software suite include (a) a text reader to develop active thinking and reading comprehension habits to build knowledge; (b) a writing and graphic organizer that moves through planning, organizing and draft-writing in content areas; (c) a talking word processor that motivates students to write, revise and edit independently; (d) word prediction that helps students compose grammatically correct sentences containing topic-specific words; and (e) progress monitoring through quantitative and qualitative data collected from individual student work and displayed as graphs, charts and previews. In the present study, use of the three writing components (Co:Writer®, Draft:Builder®, and Write:OutLoud®) to improve the writing ability was investigated.

The Participants

Cohorts of teachers at each of three levels (intermediate elementary, middle school, and high school) who had previously received training in the use of portable keyboarding devices, voice output, word prediction and/or text-to-speech reading software were recruited from a six-county area which included four special education administrative units. These teachers had received their training through a recently completed grant from the Illinois State Board of Education (ISBE) awarded to these four administrative units working as a coalition.

Each teacher then recruited two students to introduce the SOLO™ software to during writing interventions that the teachers would normally have with the students. Students with learning disabilities were selected who had writing goals and objectives in the students' IEP. Thirteen

students in elementary grades 3-5 were in the final sample; of these 11 are included in this preliminary report. Data from two of these students is being excluded due to issues with teacher scoring of their writing samples. Twenty middle school students with learning disabilities were in the final sample with two students' data being excluded due to teacher scoring issues; of the 18 in the data included in this report, two students also had behavioral disorders along with their learning disabilities. Finally, 10 high school students with learning disabilities were in the final sample; however, data sets from six students have been excluded due to scoring issues. In total, the results for 33 students across the three grade levels are included in this preliminary report. All excluded data sets (n=10) are being independently rescored and will be included in the final written report submitted for peer reviewed publication.

Training and On-Going Supports

All teachers received training in the use of the integrated SOLO™ software from DJI. Training consisted of two activities. First, groups of 4-6 teachers participated in a web-based introduction to the software package; this was conducted as the software was being installed on their classroom computers. This permitted the teachers to familiarize themselves with the software, including differences and additions to the previous DJI products that had been using. Next, the teachers all attended a one-day workshop co-presented by trainers from DJI and by two the project investigators. The principal focus of this workshop was the use of SOLO™ to support writing interventions, but features and strategies used to support reading were also examined.

Finally, these teachers participated in a monthly SOLO™ User's Group (UG) facilitated by the project investigators to support use of the software suite; integration of the software into content area writing (science, social studies, and math) and language arts writing activities; and to support use of systematic outcome measures. Instruction in the use of a systematic set of writing outcome measures developed for the project was conducted across the first two UGs. Training included a rationale for the type and frequency of the writing sample probes, how to administer the writing probes, and how to score the samples and enter the data into the spreadsheet provided to them.

Outcome Measures and Evaluation Design

The outcome measures provided for classroom-based evaluation of the effects of AT on students' abilities to complete key aspects of the writing process (prewriting and organization, production of a draft, and editing and revising the draft). Writing outcome measures included attitude toward writing as measured by the Graham and Harris (1997) *Attitudes Toward Writing* survey; this data was collected at the beginning and end of the project. Table 1 lists the outcomes variables and definitions used to assess quantity, quality and accuracy of writing samples, including quantity of words, sentence length, number of sentences and paragraphs; spelling, punctuation and grammatical accuracy. A subset of student writing samples are yet to be evaluated using the writing rubrics based on the 6+1 Traits [ideas, organization, voice, word choice, sentence fluency, conventions, and presentation (NWREL, 2005)]. In addition, data was collected regarding both teacher feedback concerning the use of the SOLO™ product during the UG meetings.

The effectiveness of the AT product was evaluated using a quasi-experimental Concurrent Time Series Measurement design, in which specific writing samples collected under three levels of technology support (concurrent measures) and with sampling over time (time series). Table 2 describes the three levels of writing support in detail. Students were asked to write for a fixed amount of time on a high interest topic to them; students could select to write narrative, persuasive or procedural writing samples. Each student served as his/her own control with comparisons of technology-supported and non-supported writing being examined over time; the full set of writing samples were collected a minimum of three times during the intervention period.

Table 1

Writing Outcome Measures

Written Productivity – Words Words are defined as a group of letters with a space on each end.	**Words/Minute**
Spelling Accuracy Error defined as a word containing at least one spelling error (Not calculated for samples <5 words).	**Avg. Errors/5-word block**
Punctuation Error defined as omitting required punctuation or inserting unnecessary punctuation.	**Avg. # errors/20 word block**
Capitalization Two types of capitalization errors: 1. Omitted capitalization following terminal punctuation 2. Omitted or inserted capitalization within sentence	**Avg. Errors/20-word block**
Sentence Accuracy	**# in Sample**
Unscorable Sentences Word groupings ending in terminal punctuation that contain an illegible subject or verb (words that cannot be recognized in context).	
Sentence Fragments Lacks a subject-verb pairing (subject or verb omitted).	
Run-On Sentences ▪ 2 sentences joined by non-terminal punctuation (e.g., comma) ▪ 2 or more "ands" within a sentence ▪ 2 or more sentences without terminal punctuation	
Grammatically Incorrect Sentence contains subject-verb paring without subject-verb agreement in predicate phrases or any subordinate clauses or containing other grammatical errors.	
Complete and Grammatically Correct Sentence contains subject-verb paring with subject verb agreement in predicate phrase or any subordinate clauses and no other grammatical error.	
Sentence Complexity (Only scored for grammatically correct sentences)	**# in Sample**
3-4 word sentences	
5-6 word sentences	

7-8 word sentences	
9 or more word sentences	

Table 2

Technology Supports Used for Producing Writing Samples

	Technology Supports Used		
	No technology	Standard Technology	Assistive Technology
Organization	None	"Graphic" organizer, e.g. checklist appropriate to task	SOLO™ writing suite ▪ Draft:Builder ▪ Co:Writer ▪ Write Out:Loud
1st Draft	Handwriting	Portable Keyboarding Device OR Word processor w/spell check & grammar check Dictionary &/or Word list	SOLO™ writing suite ▪ Draft:Builder ▪ Co:Writer ▪ Write Out:Loud
2nd Draft	Handwriting	Portable Keyboarding Device OR Word processor w/spell check & grammar check Dictionary &/or Word list	SOLO™ writing suite ▪ Draft:Builder ▪ Co:Writer ▪ Write Out:Loud

FINDINGS

Based on initial analyses of the data sets averaged across students at each grade level, preliminary findings can be posited for each of the six variables examined. These group findings will be subject to further analyses to examine the effects of type or frequency of writing instruction provided, and the use of word prediction as a tool. Finally, individual results will be examined to determine differences among learners based on initial writing ability differences. Due to scoring omissions on the part of some teachers (e.g., first draft samples were not scored), some data will be added after scoring of these writing samples has been completed.

Word Production

Word production is one of the measures that have been used to examine student fluency in writing. It is assumed that, as writers become more fluent, they are able to produce written samples that have more words in the same period of time. Word production was measured here as words/minute calculated by dividing the total number of words produced by the total time. No tech writing samples were only collected during the first and third probes; therefore, word production is not available for the no tech condition at Probe 2.

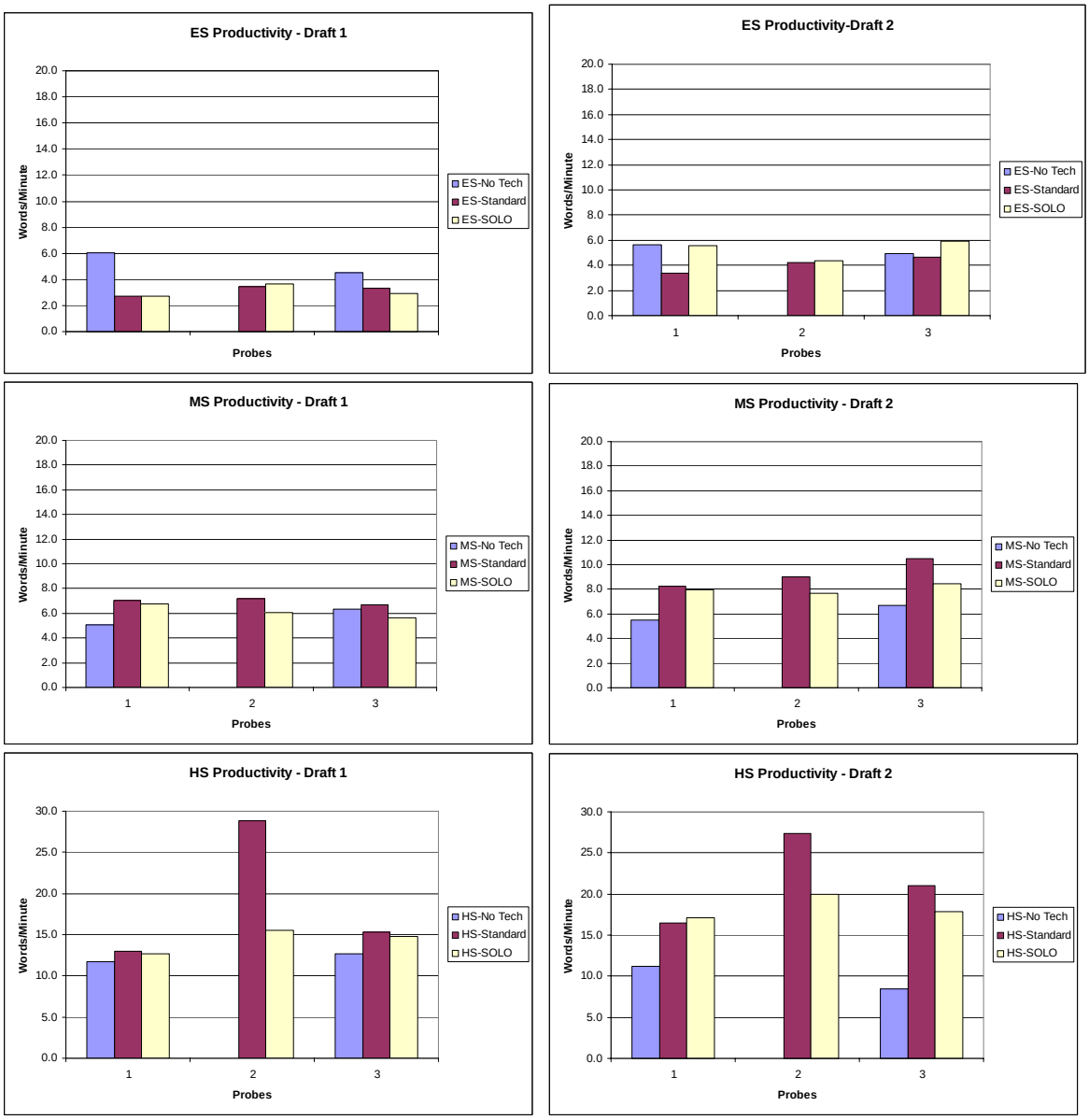
Examination of the first draft data in Figure 1 indicates that, overall, high school students have the highest levels of productivity across all three technology conditions, followed by middle school students and elementary grade students. Within the groups, elementary students demonstrated superior (6 words/min) production using handwriting during the first probe as

compared to standard and assistive writing technology (approx. 3 words/min). By the third probe, handwriting rate had declined (approx. 4.5 words/min.; probably indicating additional time being spent on content rather than output) while word production with the standard word processor and the assistive writing technology increased slightly. Such results would indicate that elementary students were becoming more operationally competent in the use of the assistive technology to transcribe. With middle and high school students, word production rates met or exceeded handwriting rates throughout the study, indicating that students with learning disabilities had already acquired functional keyboard transcription skills.

Second draft word production rates are more difficult to interpret. Word production, expressed as words per minute, can be directly compared across the no tech, standard and AT conditions for first draft only. Comparing these conditions for the second draft is confounded by the fact that no tech (handwritten) writing requires the students to completely recopy the writing sample to make revisions and edits, whereas standard and assistive writing permit the student to modify or add to an existing electronic draft without recopying. In these latter conditions, all words are counted and not just words added. Because the time to write was constant across conditions, increases in rate of word production are an indicator of student additions to the writing sample for the standard and AT conditions (more words in the sample in the same amount of time), while changes in rate of word production under the handwriting condition take into account rewriting the previous sample as well as modifying or adding to it. Results depicted in Figure 1 indicate that elementary grade students substantially increased their word production using the AT and, to a lesser extent, when using the standard technology from first to second draft across all three probes, indicating that the samples were being added to during the opportunity to revise. There is some increase in second draft no tech productivity, as compared to first draft at probe 3 possibly indicating the student were revising and adding to rather than merely recopying under the no tech condition. Middle school students also demonstrated some increases in word production rates between first and second drafts but only when using standard and assistive technologies. High school students maintained nearly equal word production rates when handwriting but increased output as indicated by higher word production rates with both standard and assistive technology. On the second draft, the superior word production rates of the high school students when using standard technology will need to be further investigated relative to the accuracy of this additional output.

Caution should be taken in interpreting the results for the high school students. First, relative to the other two groups the sample size is small and the ability levels as evidenced by the initial word production rates are substantial. Several students had word production rates nearly equivalent to the middle school students under all three technology conditions while the other students had production rates nearly three times that of the middle school mean.

Figure 1. *Word production under three modes of output.*



WRITING MECHANICS

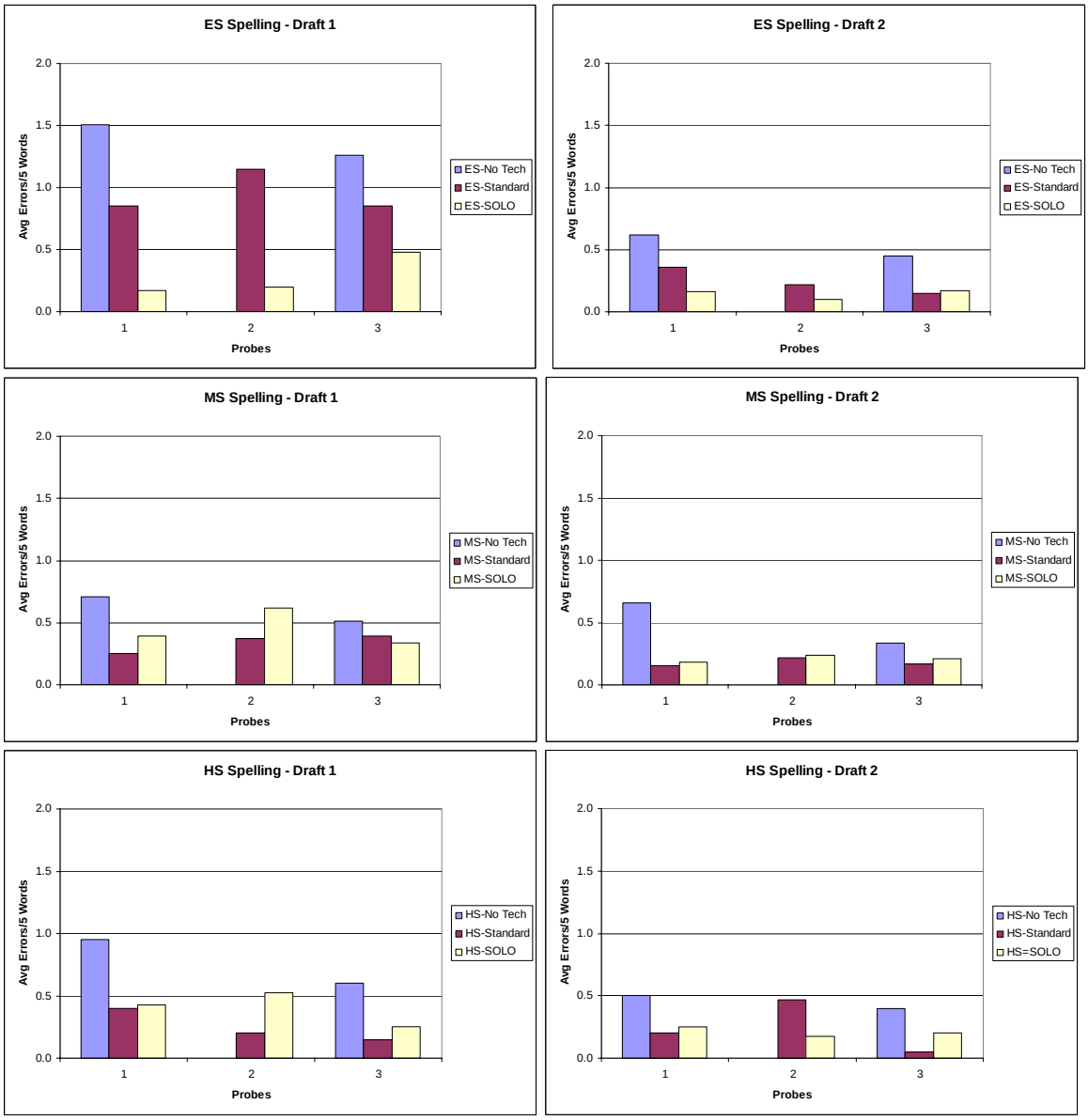
Spelling

Figure 3 depicts the average number of spelling errors per 5 word block. Examination of the first draft data in Figure 3 indicates that elementary grade students had the highest spelling error rates of the three groups. Elementary students improved their spelling very little when handwriting by the end of the study. While lower than handwriting, the spelling error rates of elementary students were still high when using standard technology. Clearly the lowest spelling error rates were achieved when using assistive technology. Middle and high school students had similar spelling error rates, with the highest rates demonstrated under the no tech (handwriting) condition. Middle school students maintained similar error rates across the study when using standard and assistive technologies. By the end of the study, spelling errors wee somewhat lower using assistive technology in comparison to handwriting and standard technology. There appear to two learning effects in both the middle and high school student data. Compared to the elementary school students, middle and high school students appear either to produce fewer spelling errors when using the standard keyboard or have initial competence in using the spell check feature. However, if they are using the spell check feature, then the high school students appear to have improved their operational competence as the study progressed, as demonstrated by the improved error rates at probe 2 and 3. Examination of the spelling error rates across probes suggest that the middle and high school students appear to have improved their use of the spelling support features of the assistive technology by the end of the study. Whether this is a function of improved use of the enhanced spell check feature or use of word prediction may be clarified when data are disaggregated.

On the second drafts (which were done following a writing conference with the teacher), all three grade levels have the lowest spelling error rates the most when using technology, both standard and assistive. Only elementary students demonstrate substantial improvement spelling from first to second draft when handwriting. While their first draft spelling error rates are relatively low when using both standard and assistive technology (1 error in 10 words or less), middle school student further decreased errors from first to second draft using technbology

In general, spelling error rates were highest under the no tech (handwriting) condition; the AT produced the largest and most consistent reduction in error rate, especially on the revised second draft writing samples, indicating that students probably paid less attention to correction of spelling during the initial draft perhaps knowing that errors could be addressed during revision. For elementary students, the AT made a substantial and immediate difference during both drafting and revising. Results would seem to indicate that middle and high school students already had some skill in use of the standard technology spell check feature.

Figure 2. *Spelling errors under three technology conditions.*



Punctuation

Examination of Figure 3 reveals positive effects of technology use on punctuation error rate per 20 words written by students at all three grade levels. During drafting, the lowest punctuation error rates were demonstrated under the AT condition in 6 of the 9 probes across all three groups. On first drafts, all three groups made the most errors under the no tech condition. At probe 1, high school students made more first draft punctuation errors under the AT condition than under no tech or standard tech, although all error rates are low. On first draft samples, middle school students made the fewest punctuation errors using assistive technology across all three probes. High school students appear to improve their use of assistive technology as evidenced by the decreased punctuation error rates at probes 2 and 3, compared to probe 1. During revision (draft 2), punctuation error rates were highest under the no tech condition in 5 of 6 compared to use of both standard and assistive technologies. At the end of the study (probe 3) elementary students made the fewest errors using assistive technology, while middle and high school students had comparable rate using standard and assistive technologies with high school students achieving the lowest rates. The unusually high error rates evidence by the high school students when handwriting (no tech) at Probe 3 will need to be examined further

Capitalization

As depicted in Figure 4, elementary students appear to have benefited dramatically from the use of the AT, demonstrating very low rates of capitalization errors (per 20 words) on first second writing samples in comparison to substantial errors under the no tech and standard technology conditions. On first drafts, middle school students initially make the least capitalization error using assistive technology. However, while the error rate is comparable at the end of the study using AT, error rates using standard technology have decreased. The reasons for this will require further analysis. Overall, capitalization error rates (average per 20 words) were lowest for high school students, with the exception of Probe 3, on both first and second drafts. From first to second draft, both elementary and middle school students generally reduced their capitalization error rates when using both standard and assistive technologies with the most improvement at probe 3.

Elementary and middle schools students have the lowest error rates using AT on both first and second drafts in 10 of 12 probes. They also had the highest errors under no tech in 7 of 8 probes where no tech was used. Comparing assistive to standard technologies, capitalization error rates are lower using assistive technology in 9 of 12comparisons across both first and second drafts and nearly equivalent in 1 other. These results suggest that the assistive technologies provided elementary and middle school students the most support for capitalization.

Figure 3. *Punctuation errors under three technology conditions.*

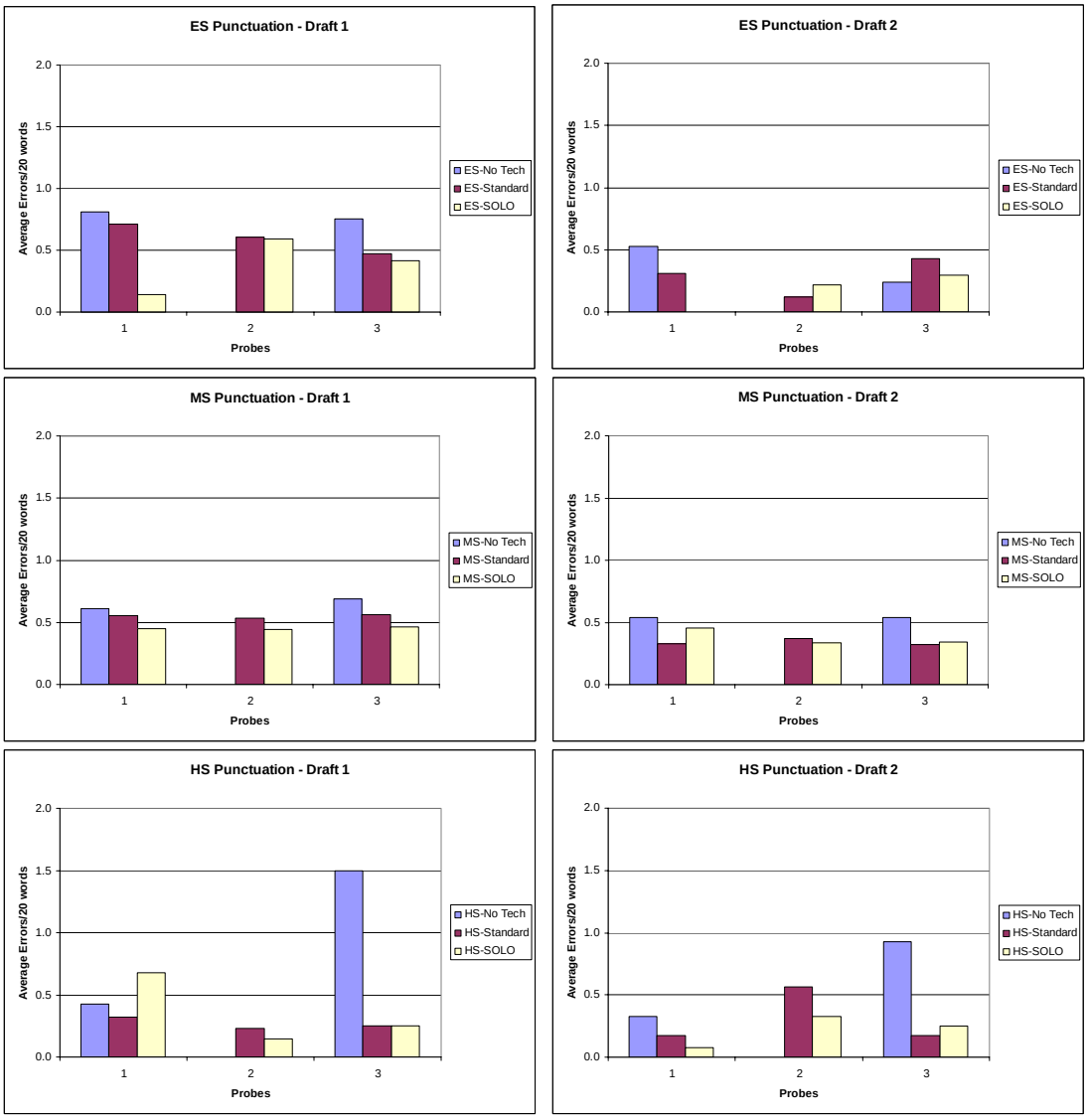
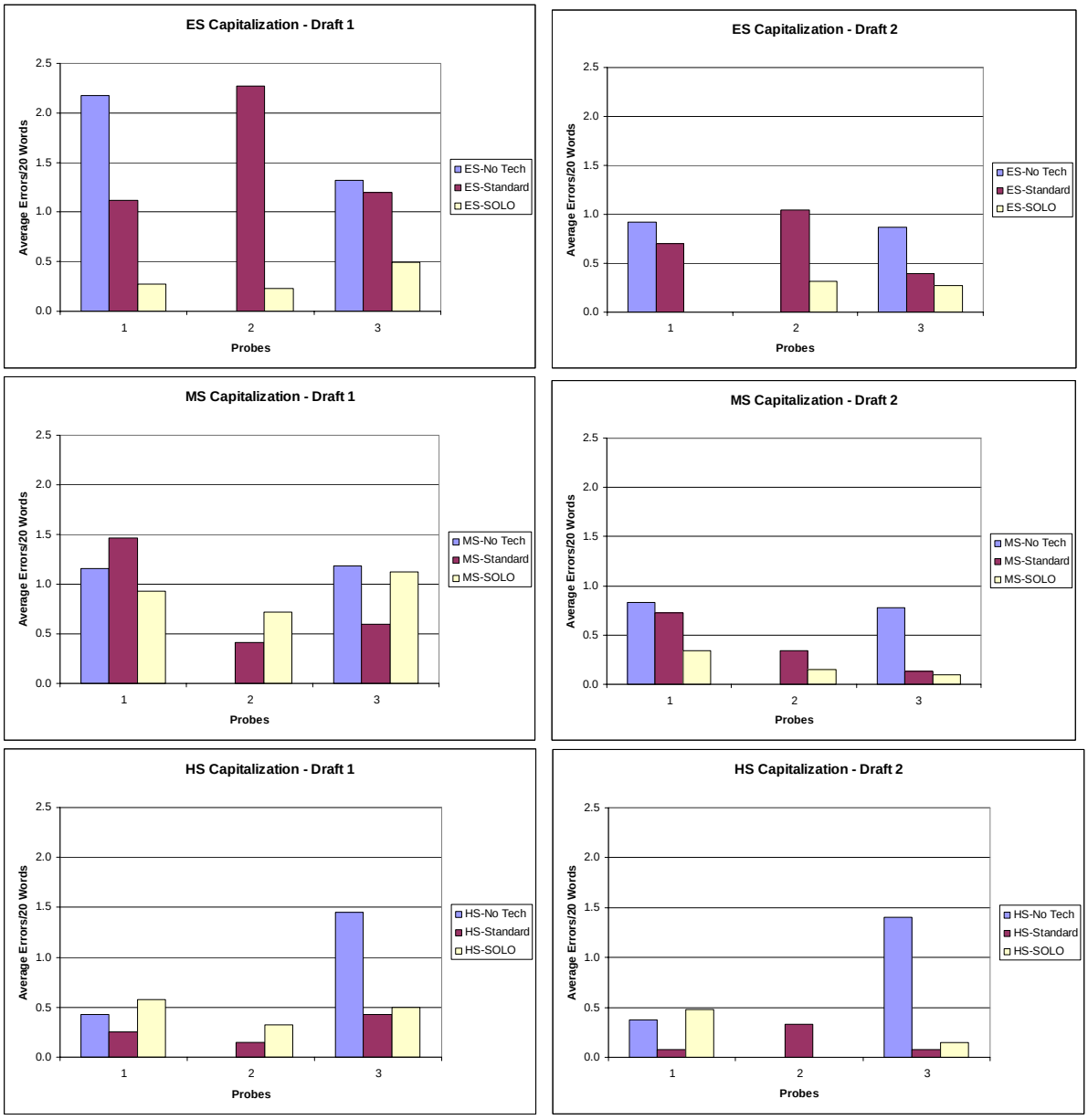


Figure 4. *Capitalization errors.*



Sentence Accuracy and Length

Sentence Accuracy

Accuracy of sentences in this study was used as a measure of the student's writing quality. Several different types of sentences were scored in this category including the student's use of sentence fragments, run-on sentences, and grammatically incorrect and correct sentences. Every sentence in the writing sample was judged using a set of decision rules (in the form of a flow chart). The basis unit of analysis was the presence of at least one subject-verb pair. An additional type of sentence type was created to take into account student spelling or handwriting issues. A word might appear in the subject or verb position in the sentence, but this word was "unrecognizable" in that either the spelling or the handwriting made it impossible to determine its meaning without guessing from context. When this occurred, the sentence was judged to be "unscorable." Only sentences with recognizable subject-verb pairs were judged for grammatical completeness and accuracy. If the sentence lacked a subject-verb pair, it was considered to be a sentence fragment. Sentences with two or more subject-verb pairs (not in subordinate clauses) that lacked conjunctions or three or more subject-verb pairs (not in subordinate clauses) that were joined with conjunctions were considered to be run-on sentences. Sentences that were not fragments or run-ons but which lacked subject-verb agreement, including those in subordinate clauses, were grammatically incorrect, while those which had subject-verb agreement were grammatically correct.

Figure 5 depicts the average number of sentences in the writing samples for each group of students across probes and technology conditions in the first draft samples. Examination of Figure 5 shows that, across elementary, middle and high school students, the assistive writing technology condition produced the lowest number inaccurate sentences (fragments, run-ons and grammatically incorrect) across all probes and with the preponderance of sentences being grammatically correct. The data also demonstrate that students across all three grade levels produced very few sentence fragments. In general, the students' errors were either run-on or grammatically incorrect sentences. The data also demonstrate an increase in grammatically correct sentence across the grade levels regardless of the production mode, indicating a maturation effect for writing accuracy.

As suspected, under the no tech condition, the most unscorable sentences occurred; surprisingly however, this was limited to the elementary and middle school students. High school students produced few unscorable sentences under any of the conditions. Again, this result must be viewed in light of the range of ability demonstrated among the high school students with learning disabilities in this sample. Under the standard technology condition, elementary student produced a mix of unscorable and inaccurate sentences while middle and high school students produced the most run-on sentences (as compared to no tech and assistive tech).

Sentence Length

The number of words occurring in grammatically correct sentences was used a proxy measure of sentence complexity. Accurate sentences of 7-8 words should include more information than will sentence of 3-4 words. Grammatically correct sentences were placed into four possible ranges: 3-

4 word, 5-6 word, 7-8 word and 9 words or more. Figure 6 depicts the analysis of sentence length across the three groups under the three technology conditions in the first draft samples.

Examination of Figure 6 indicates that elementary grade students wrote lengthier, and presumably more complex, sentences using AT; the most 7-8 word grammatically correct sentences were written at probes 1 and 3 and the greatest number of 5-6 word sentences composed occurred at probe 3. At Probe 2, elementary students demonstrate an atypical increase in sentences of 9 or more words. It appears that slightly more, longer sentences were composed using standard technology in comparison to no tech, but still less than using AT.

Middle school students also composed the most grammatically correct 7-8 and 9 or more word sentences using AT (especially at probes 1 and 3) as compared to the two other conditions. Interestingly, the combined number of 7-8 and 9 or more word sentences under the standard technology condition would have match the AT if not for the spike in 3-4 word sentences at probe 2. Middle school students wrote the fewest number of 3-4, 5-6 and 9 or more word sentences under the no tech condition at probe 1 but appear to have benefited from the writing experiences as revealed in the greater number of sentences of 3-4, 5-6 and 7-8 words produced in the probe 3 no tech samples.

The data for high school students demonstrates that these students wrote the most, longer sentences of the three groups under all three of the technology conditions, specifically, 7-8 word sentences. However, these results are probably most affected by the disparity in initial writing skill across the students in the sample. These results will need to be re-examined when the initially high performing students' data are disaggregated in the sample.

Figure 5. *Sentence accuracy in first draft samples.*

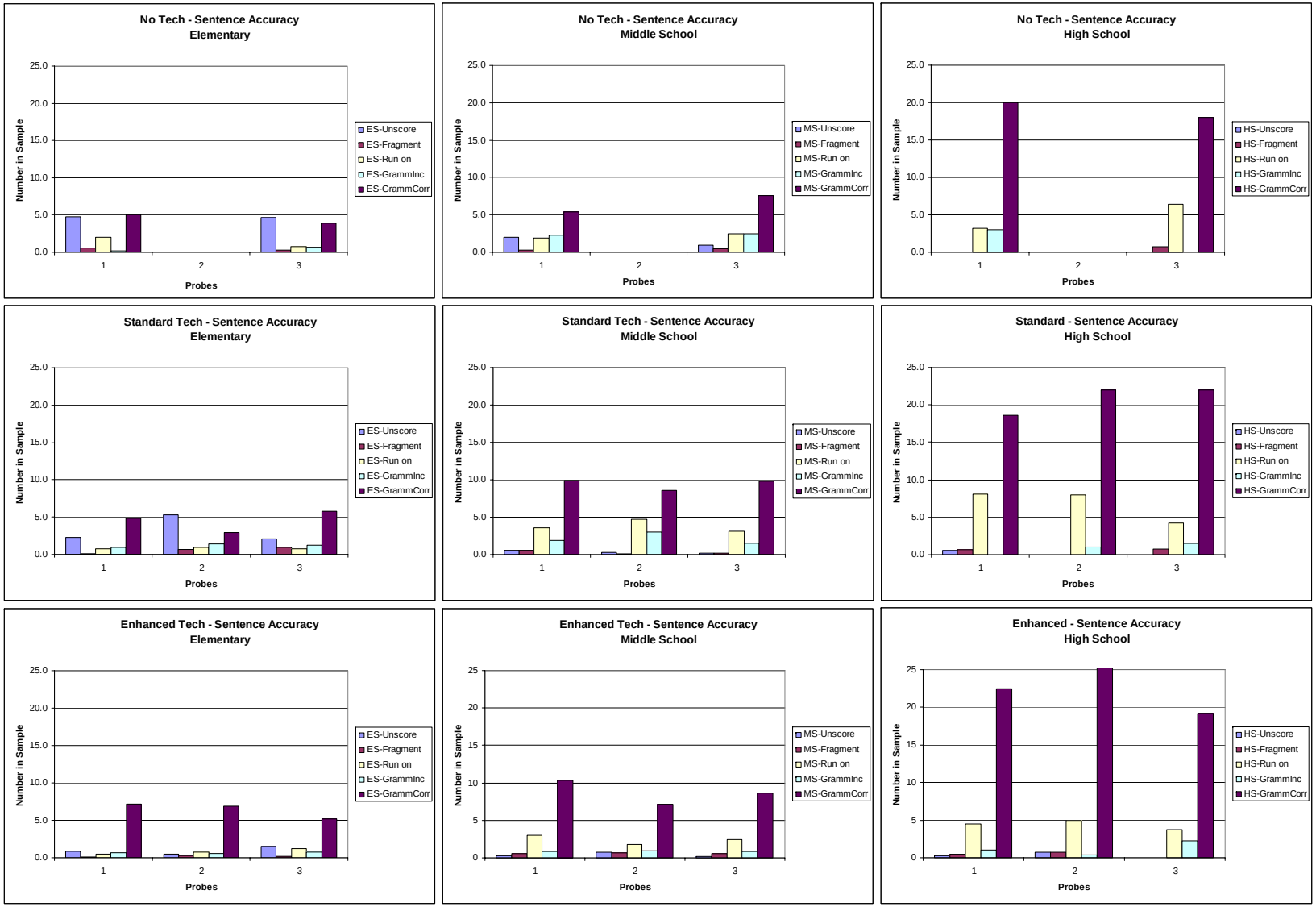
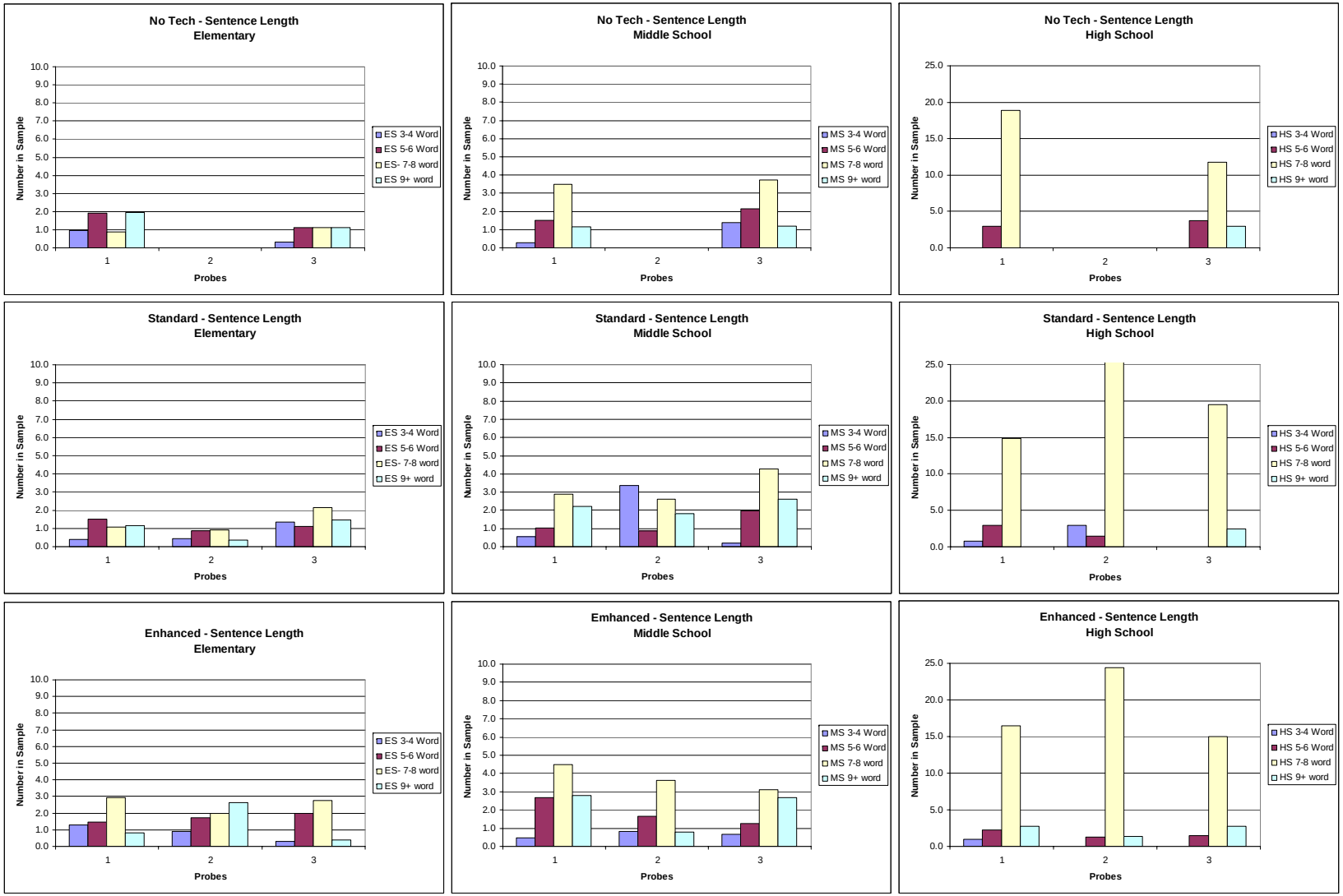


Figure 6. *Sentence length (complexity) in first draft samples*.



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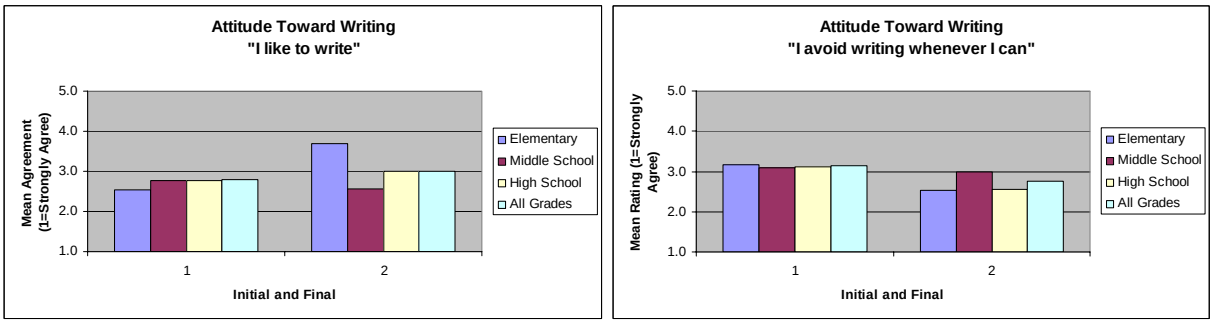
Attitude Toward Writing

To determine whether student attitude toward writing changed as a result of experiences in using standard and AT, students were administered a 6-item survey. The primary items of interest were "I like to write" and "I avoid writing whenever possible" to which students could answer on a 5 point scale from strongly agree (1) to strongly disagree. Figure 7 shows the mean ratings by grade and across all grades.

Figure 7. *Attitudes toward writing*.



Overall, students with learning disabilities are either neutral or slightly negative in their attitudes toward writing initially. At the end of the study, students in elementary grades appear to have declined in their attitude toward writing as expressed in greater disagreement with the item "I like to write." Middle and high school students are substantially unchanged. Elementary and high school students appear to be slightly more inclined to avoid writing while middle school students are unchanged. The various technology conditions were not separately rated, so it is unknown the extent to which providing writing samples under the three conditions affected the students' attitudes positively or negatively.

CONCLUSIONS

Before considering preliminary conclusions that can be drawn from the results of the research, it must be recognized that the validity of these results is subject to determination of the reliability of the data, Specifically, reliability analyses of the teacher scoring of writing samples is currently being conducted. Further, statistical analyses of the significance level of the differences noted below have not yet been completed. With these cautions in mind, the following conclusions are offered:

1. **Word Production**. The use of technology (standard and assistive) produced rates of word production that met or exceeded the no tech (handwriting) condition. Since this was true even at Probe 1 for the middle and high school students, it would appear that the students generally already had some keyboarding skill and that they were able to use this skill to compose more quickly using the keyboard than by hand. Increases in word productivity rates from the first to the second draft when using standard and assistive technology indicates that students are also adding words, i.e. revising content. Effects of

the use of word prediction on word production will be determined by disaggregating word prediction users.

2. **Spelling**. The assistive technology produced the largest and most consistent reduction in spelling error rates, especially on the revised second draft writing samples, indicating that students probably paid less attention to correction of spelling during the initial draft perhaps knowing that errors could be addressed during revision. For elementary students, the assistive technology made a substantial and immediate difference during both drafting and revising. Reductions in spelling errors using both standard and assistive technologies, in comparison to handwriting, would seem to indicate that middle and high school students already had some skill in use of the standard technology spell check feature. Further analyses of the data will be completed to determine (a) the effect of the use of the word prediction feature on spelling and (b) the effect of technology relative to students' initial ability levels.

3. **Punctuation and Capitalization**. Both standard and assistive technology produced lower punctuation error rates. Especially striking was the reduction in first draft punctuation errors by elementary students using the assistive technology across all three probes. High school students demonstrated substantially reduced first draft punctuation errors using both standard and assistive at the end of the study. Compared to handwriting, both standard and assistive technologies resulted in substantial reduction in second draft errors at the end of the study across all three grade levels, with assistive technology having the greatest effect for elementary and middle school students. Assistive technologies appeared to have provided elementary and middle school students with the most support for capitalization, although in comparison to handwriting, using standard technologies also reduced errors by the end of the study. High school students, with one exception generally attained low spelling error rates when writing regardless of the technology used. In Probe 3, when no tech capitalization errors were unusually high, very low rates were still achieved with standard and assistive technologies.

4. **Sentence Accuracy**. During first draft writing, when using the assistive writing technology, all three grade levels of students with learning disabilities, produced the lowest number inaccurate sentences (fragments, run-ons and grammatically incorrect) across all probes, with the preponderance of sentences being grammatically correct. Using AT, sentence fragments and grammatically incorrect sentences were nearly eliminated. Elementary students nearly eliminated run-on sentences using AT while middle and high school students demonstrated reduced numbers of run-on sentences. As expected, the use of technology (standard and assistive) virtually eliminated unscorable sentences; these were sentences containing subjects or predicates that could not be evaluated for agreement due to unrecognizable ("illegible") words.

5. **Sentence Length**. Overall sentence length increased as students matured. However, using AT, all three grade levels of students with learning disabilities wrote more, longer grammatically correct sentences during first draft writing. Middle and high schools students also produced more grammatically correct longer sentences using standard technology than they did when handwriting (no tech).

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