

Handwriting Legibility: A Method of Objective Evaluation

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A rationale and method is presented for objective evaluation of handwriting according to legibility criteria for the roman alphabet and its slanted version, italic: letter angle, letter length, spacing between letters, and the shaping of counter spaces. Inaccurate performance of letters according to these criteria reduces legibility in our roman-reading culture in proportion to deviation from the system of visual order. Measurement procedures and a flowchart description of the computer process are given. Preliminary findings of a comparative study being made between the commonly taught printscript and a simple italic hand are noted and identified for potential use in modification of curriculum design and teaching practices.

As a quality of handwriting, legibility denotes the formal adequacy of the letters to communicate, and results from high formal correspondence between the handwriting and a model that the reader is prepared to recognize. Legibility is a natural consequence of handwriting produced with distinctive, simple letter models in proportioned form.

The notion of a written alphabet (i.e., a "visual system" of letters) implies a law of order that precedes the individual letters as a cause of visual harmony. For example, the structural design of one letter of a system implies the structural design criteria for all other letters needed for that system. The distribution of scale, proportions, letter angle, and interspace predetermine the system's structural requirements.

Although each letter of a system has distinguishing characteristics of design that are confirmed by wide, consistent use and family relationships with other traditional alphabets, the ability of the form of the individual letters to communicate must be judged in word-producing combinations intended for reading, for reading is the final cause of writing. The evaluation of any handwriting according to structural specifications of the pattern determining the creation will

indicate whether or not it can be expected that the writing will be accurately and quickly deciphered by a reader trained in the literacy norm of the culture. It will also suggest whether the handiwork is relatively immune to inaccurate performance under the pressure of speed.

The cause of handwriting legibility is consistent performance of a hand according to a culturally universal visual standard. The standard of the English language is the roman alphabet in the upright and slanted version, italic.¹ Form correlation of many handwriting performances to the many design variations of the roman letters is possible only if the handwriting is objectively measured with the traditional production criteria common to the roman letters: letter angle, vertical length, internal counter shape, and the space between letters. Inaccurate performances of letters according to these criteria reduce legibility in our roman-reading culture in proportion to the extent of the visual deviation from the system of visual order.

The most convincing evidence to support this idea is the principle's use in the common practice of all lettering craftsmen. These elements of basic design: letter slope, space, scale, and shape are fundamental to their work of typography, sign lettering, calligraphy, *et al.*, which requires ease of reading beyond legibility.² Handwriting, lettering, and typography must satisfy objective and optical requirements to be legible to the reader. Letter images produced either by hand or mechanically share the same criteria of structural development which serve as the basis for judging the relative effectiveness of various production tools, materials, and techniques. To quote Stanley Morison, "The laws governing the typography of books intended for general circulation are based first upon the essential nature of alphabetical writing, and secondly upon the traditions, explicit or implicit, prevailing in the society for which the printer is working."³

The essential nature of alphabetical writing, as determined by Alfred Fairbank, is a "system of movement involving touch."⁴ It is the system of handwriting movement that provides the objective and measureable ground for evaluation and research, and many behavioral researchers have built their work around the principle of analytical handwriting evaluation.⁵

The notion of "general merit" of handwriting has been used in many cases as the criterion most suited for evaluation of handwriting.

A summary of the various systems is presented by Virgil E. Herrick and Adrienne Erlebacher.⁶ The authors' definition of "general merit" of handwriting, as based on Thorndike's work, "included the artistic or pleasing quality of the writing in addition to its clarity and uniformity of line and form" (p. 212). The authors later support the adoption of "general merit" of a sample of handwriting both "as a criterion for producing handwriting scales and for placing handwriting samples on them." This decision was made by excluding other alternatives which included "single objective measures" (e.g., letter slant, spacing) because "measures made of these factors fail to distinguish between handwriting samples which are clearly different in general merit" (p. 213).

This position represents the rationale of most efforts to evaluate handwriting legibility in public education today. Unfortunately, "clarity and uniformity of line and form" results in a judgment that certain writing is more or less legible without saying why it is so. As a basis for educational diagnosis, the criterion does not supply the kind of evidence needed. Relative legibility is best evaluated by single objective measures of specific deviations from the prescribed forms of the various versions of the roman alphabet and its slanted version, italic.

When is handwriting illegible? Illegibility can be relative to a reader's training for deciphering the message. The commonly accepted "commercial cursive" system is relatively illegible to a first-grade student who is untrained in the models. But when is handwriting relatively illegible to a trained reader? When the alphabet symbols are not produced according to certain minimum criteria of form.

The Criteria

The qualities of size, shape, and position are aspects and implications of the space definition and design created by each letter and word. The following production criteria are another way of expressing these qualities and can be used to determine the frequency, kind, and extent of form deviation in handwriting. Considered together, they are the formal cause of legibility in our cultural standard, the roman alphabet and the slanted version italic.⁷

Letter Angle. Without consistent, harmonized alignment, the reader is required to decipher individual letters rather than symbol patterns, with resulting greater number of eye sets.

Space Consistency Between Letters. Generally, handwriting legibility is improved by even appearing spacing, that is as close as practical. Widely spread handwriting requires greater concentration and confuses perception. Combinations of letters should appear to be equally spaced.

Vertical Length of Letters. The idea of length is less ambiguous than height. Length encompasses the possible evaluation of ascenders, letter body, and descenders. The criterion itself is an aspect of scale, shape, and vertical position.

Counter Space Shape. This criterion is the direct evaluation of form as space definitions that are simultaneously designed white areas, both inside and outside the strokes of the pen. This one measurement indicates the directional thrust and structural magnitude.

Applying the Criteria

Each of the four criteria lend themselves to a practical, convenient measurement for objective analysis of handwriting. Used together they are thorough and individually adaptable to roman or italic letters performed in any conventional handwriting sample. In an actual evaluation, all of the criteria measurements are derived from the model alphabet which is furnished in a format of handwritten words in a sentence. Again, the object of all criteria measurement is to determine frequency, kind, and extent of deviation from the model visual system. A typical sample sentence in a handwriting evaluation is designed to contain all the letters of the alphabet (Fig. 1). For example, the most commonly used sentence is "The quick brown fox jumps over the lazy dog." Evaluation of a handwriting effort is concerned with the production of lower-case letters. The reason for the exclusion of capitals is that a capital letter is regarded as drawn rather than written; and the idea that handwriting is "a system of movement involving touch."⁸ Objective measurements of the handwriting performance cannot analyze the quality of movement in the act of production, but they can report the relative structural harmonies of the after effects.

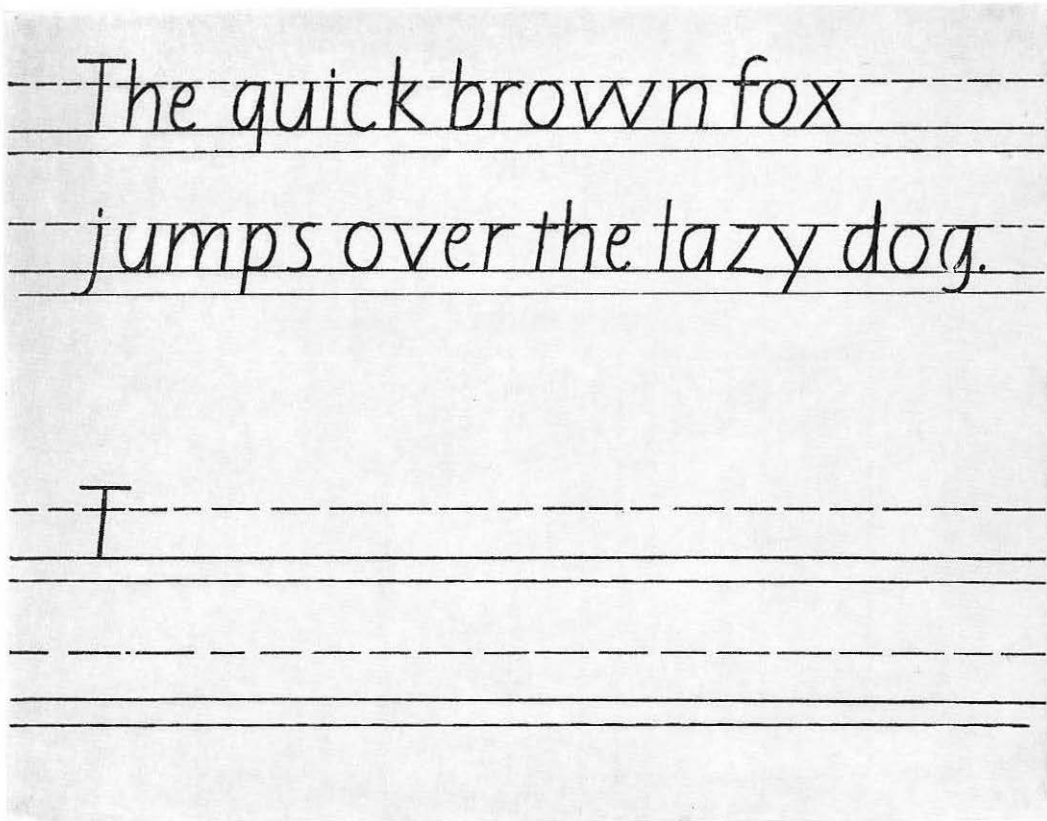


Figure 1. Sample of the worksheet used to gather data from italic-writing students.

Two tools are necessary for tallying the measurements: a score sheet and a computer. The score sheet lists all the letters of the sample sentence down the side of the page and the criteria across the top. Each letter of the sample sentence to be evaluated is then measured four times, once for each criterion. As a deviation measurement is taken, the results are recorded under the appropriate column, opposite the appropriate letter.

Letter angles are measured with a transparent overlay (Fig. 2). The overlay has a horizontal series of lines appearing across it ranging from a 5-degree left tilt at the left side of the page, through vertical zero at the middle, to a 15-degree right tilt at the right of the page. The

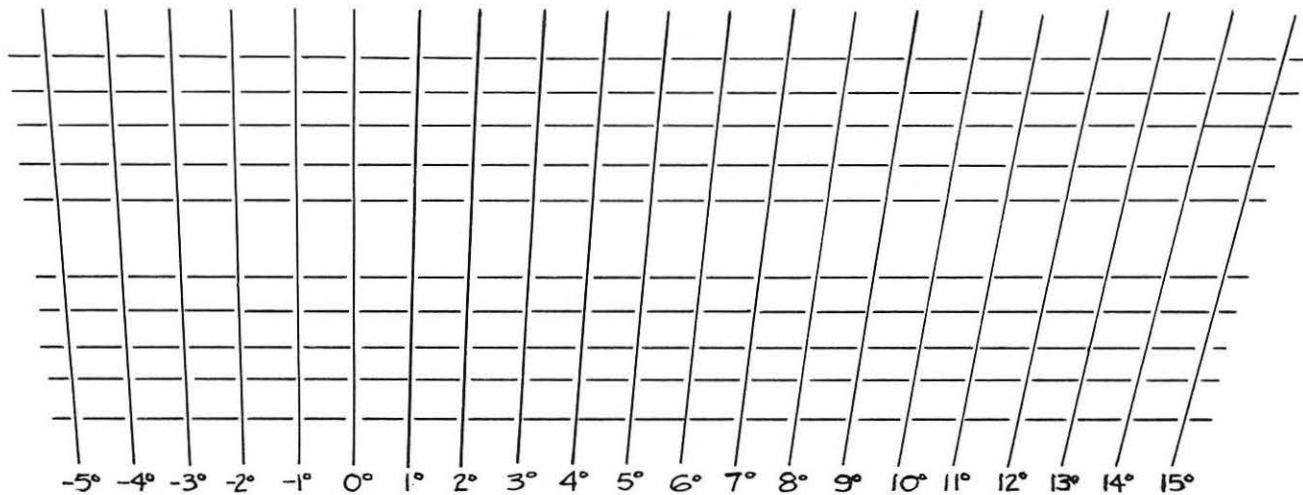


Figure 2. Design for the transparent overlay used in the measurement of letter angles.

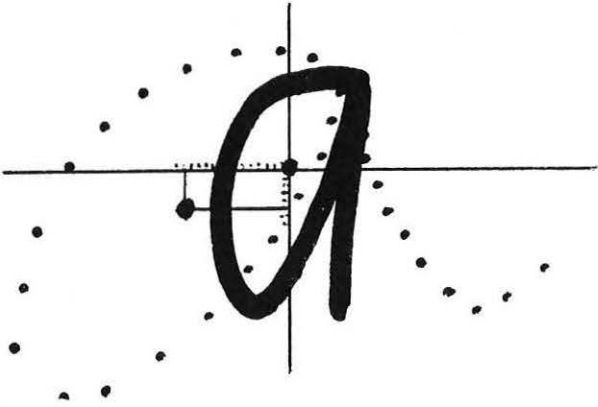


Figure 3. Design for the transparent overlay used in the measurement of shape dislocation. The dotted line indicates a student sample; the black line, a model letter.

series of angled lines is crossed by horizontal lines to serve in lining up the transparency on the sample sheet to be measured. To facilitate taking letter angle measurements, it is best to make them from absolute vertical zero and record them as plus or minus degrees from the vertical zero angle. If the model is designed to slant to the right—as in the case of italic handwriting or commercial cursive—the computer can be required to make the adjustment to a relative value during the tallying process.

The second and third criteria, letter spacing and length, are also absolute measurements in millimetres. The spacing between letters in the model sentence will vary, and the computer can adjust the absolute measurements of the sample writing to be relative to the different spaces of the model letters.

The fourth criterion, counter space shape, requires a double measurement. The intent is to provide numerical evidence of shape deviation from the model. Measurement of the shape's visual axis displacement indicates changes in the structural size and location. The method is to use a transparent overlay that has the model alphabet sentence on it (Fig. 3). The scorer marks a dot at a key optical axis of each letter on the transparency and on the written sample to be evaluated. The appropriate transparent model letter is then aligned over the sample letter being evaluated, taking care to align the stems or, in the case of the letter "o," the logical first stroke

of the letter. If the sample letter has incorrect letter angle, the model must be aligned to it correctly according to the system on the basis of the evaluator's judgment of where an essential structural element is available. In this way it is possible to measure each letter angle, length, and shape in spite of any misplacement away from the sample sentence. The fact of any misplacement, as a deviation in itself, is reported in the spacing measurement.

After positioning the overlay, the evaluator then imposes a second transparent overlay with a cross that has all four branches divided into millimetres. The axis of the cross is placed on the axis of the model letter with the vertical branch aligned with zero degrees letter angle. The measurement then is a task of counting the millimetres of displacement from the optical axis of the model letter to the optical axis of the sample letter. The count is made in both directions on the branches of the cross, known commonly as a Cartesian Grid. For example, the optical axis of the sample may be displaced downwards to the left. In this case the evaluator reports the horizontal deviation under the fourth column on his score sheet as a certain number of millimetres with a minus sign since the displacement was to the left of where it should have been (plus if to the right). Then under the fifth column of the score sheet, he reports the vertical displacement as a certain number of millimetres, again a minus score because the displacement is downwards from the intersection of the grid. The vertical and horizontal branches of the cross in the Cartesian grid are commonly referred to as x and y . A score entry of zero under either of the columns would indicate that the sample did not deviate from the model in that direction.

Many questions of interpretation arise during an evaluation. Consistency of judgment is essential and simple principles help form guidelines. For example, the top half of a letter is more important visually than the bottom half.⁹ Therefore: (1) In siting the key counter axis in a letter that is shaped with equal counters in the model form, use the top counter (as in x , k , and s). (2) In other letters with balanced counters (such as f , t , z) commit to one counter area that is common to the group—in this case the lower-right counter space. The letters i and l do not have counters and the scoring of the fourth criterion in their case should be a “zero deviation.”

If a letter is omitted, the scoring should regard it, in all criteria, as

zero deviation. In the current project, the evaluators found less than one percent of the letters omitted from the sentences evaluated. Even though the computer tallies the omission as a perfect score for each criterion, it has no significant bearing on the final score.

The computer program computes—as phase one—the class performance averages and standard deviation rates in each of the four criteria applied to every letter of the handwriting sample, letter by letter. In a second phase of computer tally—using the averages and standard deviations from the first computer run—the performance by groups of classes can be compared to evaluate the effectiveness of two different handwriting systems, letter by letter, criterion by criterion. The third and final phase of computer tally reduces the criteria performance scores of each group to an average of the standard deviation rates for each criterion.

The educational value of this “three stage” approach to objective research in handwriting can be judged by the information it provides. Performance deviations of each criterion of legibility of the roman alphabet are gradually synthesized from three specific viewpoints: a classroom teacher’s need of close detail, for diagnosis and prescription; the administrator’s need of simplified group performance data; and the administrative need for concise, convenient comparisons of research findings.

The Computer Program

The computer program—written in Fortran IV for the Honeywell 1200 computer at the University of Portland—was originally designed in two parts to be sure that computer memory size was no problem. The two programs are designed in a way that will allow them to be combined later. See Figure 4.

The first program takes the keypunched data, checks the code for “traditional” or “italic” letter forms, tabulates deviations for the five criteria used to evaluate legibility, and adjusts for each letter model’s relative slope, space, scale, and shape. Averages and standard deviations are calculated. The printout gives the group code, a listing of tallies of each criterion’s deviation, average and standard deviation. This is repeated for all the letters of the sample.

The second program takes from the first program the average and standard deviation for each criterion of each letter. An average for

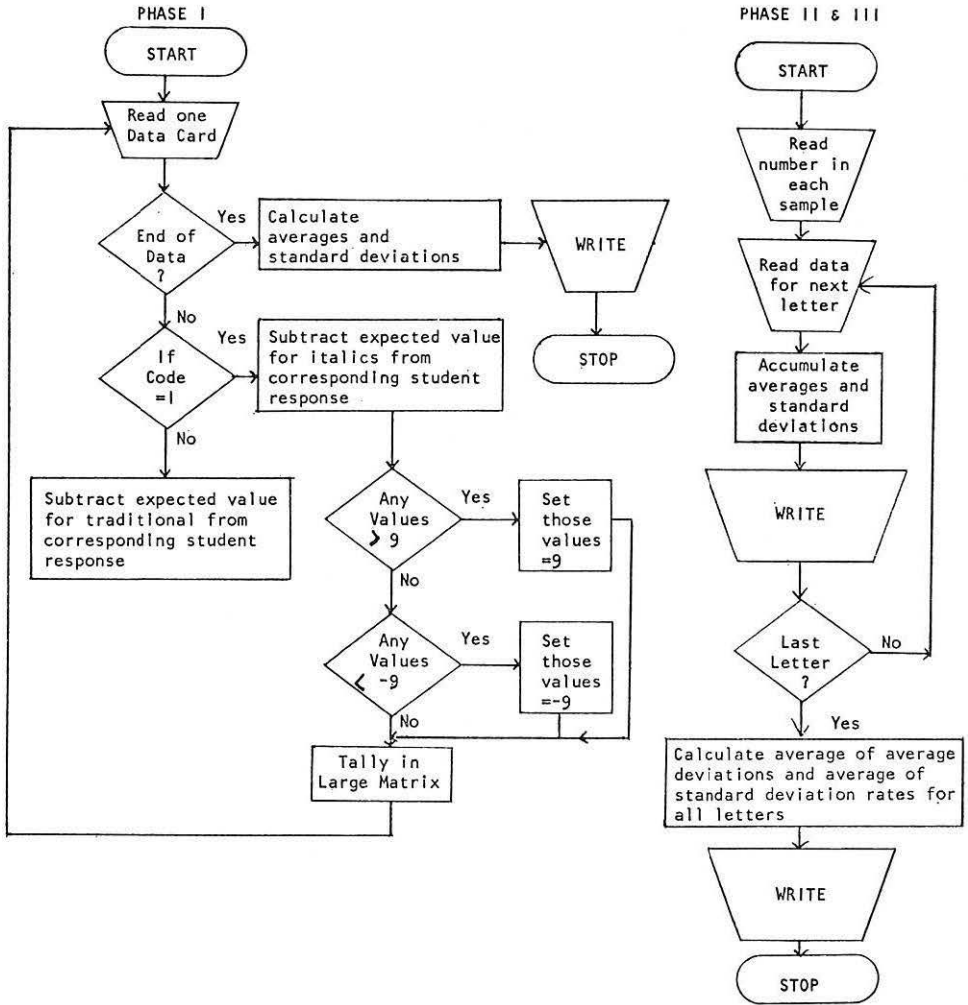


Figure 4. Flowchart for the computer program.

each group is calculated. (We chose to average the standard deviations to provide a simple indicator that would show some significance but not require a person to understand a great deal of statistics to find the indicator meaningful.) The output is a letter-by-letter average and average standard deviation for the style of letterforms. The final output averages the standard deviation rates of all letters for each of the five criteria for traditional and italic letterforms.

The entire computer program was designed and conducted by Paul Peck, chairman of the mathematics department in the secondary schools of Tigard, Oregon. A complete program listing is available from the author with model sentences, scoring sheets, computer cards, and sample printouts.

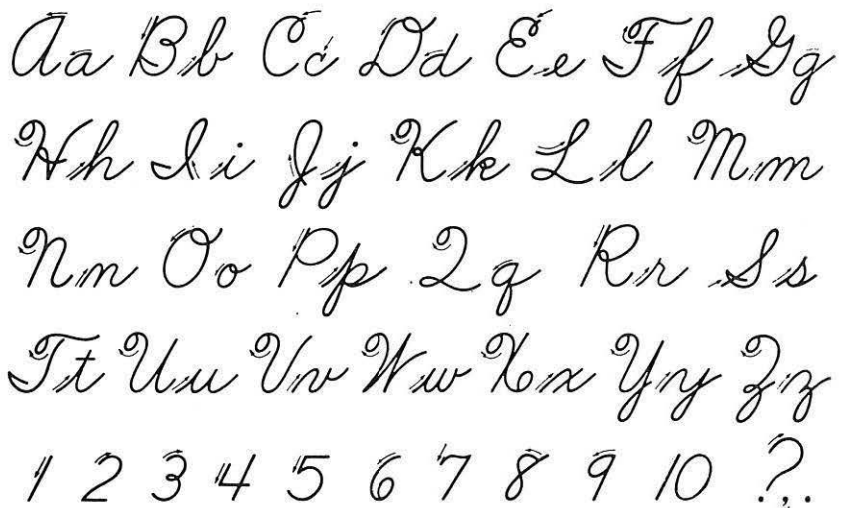
FIRST RESULTS OF A CURRENT PROJECT

The rationale of legibility and objective measurement described in this article is the basis for a current handwriting research project in Tigard Public Schools, a medium-sized school district located in a suburb of Portland, Oregon. The object of the investigation is to evaluate simple italic handwriting as a primary grade instructional alternative to the commonly used printscript and commercial cursive. The degree of complexity and nature of the research method were determined by two considerations:

1. In addition to a conventional subjective evaluation based on surveys of parent and teachers, a thorough objective method of investigation was designed and adopted to provide creditable and convincing evidence to educational and behavioral researchers. Any claim of educational effectiveness for an instructional program must be supported by clear evidence that the program can change student behavior in a way that can be observed and measured. In the case of italic handwriting, it is claimed that the educational continuity provided by using one unjoined set of letter models in grade one (which are modified slightly during the second grade by joining the lower-case letters) allows the student to go on learning as he began and results in a more efficient handwriting performance. Further, it is claimed that the use of elliptical letter models derived from the italicized roman alphabet are easier to perform than the circles and vertical lines of printscript. See Figures 5 and 6.



Figure 5, top to bottom. (a) Printscript, usually taught in grades one and two only. (b) Commercial cursive, usually taught in grade three and all subsequent grades. (c) Lower-case commercial cursive wordlist.



Other criticism notes that the changeover from printscript to commercial cursive early in the third grade causes many children to become frustrated by the severe break in continuity and the confusing forms of commercial cursive. Printscript is charged with being bad preparation for commercial cursive because:¹⁰ (a) It uses pen lifts; commercial cursive doesn't. The lack of joins and use of pen lifts makes it impossible to relate printscript to handwriting. (b) It standardizes letter parts, making them accident prone. (c) It demands exceptional motor coordination to perform circles and straight lines, when the hand and eye are best at elliptical shapes and slanting lines. (d) At a critical age of perception training, printscript ignores the essential nature of handwriting: rhythmic movement.

Further, charges are brought against commercial cursive systems and letters: (a) The commercial cursive (all of the nineteen or more "systems" taught in American schools) are accident prone. (b) Due to standardized letter parts, the letters tend to look homogenized. (c) They slope too much. (d) The loops of ascenders and descenders are distracting. (e) The body height is disproportionately small. (f) The joins are visually as important as the letters.

coat king inside tonight

kind rest dress wet

fly hay light grass

start near air end

boat fish might pull

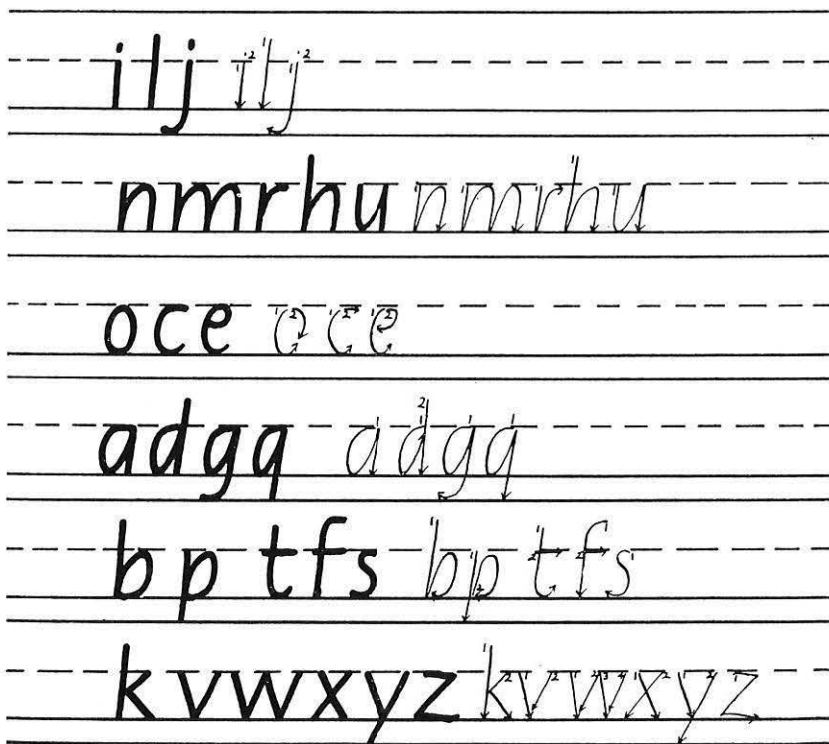


Figure 6, clockwise from above. (a) Lower-case italic (in basic teaching “families”) as taught in grade one and all subsequent grades. (b) Upper-case italic in width groups as taught in grade one and all subsequent grades. (c) Same lower-case italic as joined for full cursive hand development during grade two.

2. All of the charges made against printscript and commercial cursive and all of the claims made for italic handwriting are concerned with formal qualities of the letter models that will make their learning and handwriting performance relatively easy or difficult for the student. This fact suggested the hypothesis and method of research: students who are taught italic handwriting as a basal system will deviate less in their handwriting from the formal requirements of the letter models taught to them than will students who are taught printscript and commercial cursive.

wide O C D G Q O C D G O

H A N T K H A N T K

M W U V M W U V

X Y Z X Y Z

narrow B E F I J B E F I J

L P R S L P R S

in line lit jet let me
dinner unmarked
him her it ice coke
and dog quick bad
baby pet pad try up
fun try snow sight
very video love ivy
wet wire window
x-ray ox yes yipes!

In the Spring of 1971 six first grade classes were selected for the pilot study. The classes were all in elementary schools in or near Tigard. Some are public and some are private. Beginning in September, 1971, three classes studied italic and three studied printscript as their basic first-grade handwriting instruction. The research is designed to last three years, tracking the students through the third grade which is the usual period for transition from printscript to cursive.

The simple italic alphabet of Alfred Fairbank was selected (with minor modification of the G and t) as the model to be evaluated. The models were adapted from the Beacon series of student work-books. New program materials were designed which included exemplar cards, student worksheets, and a teacher guide. The Noble and Noble printscript program was selected because it is representative of all three handwriting programs adopted in the State of Oregon, and it is the current official adoption of the Tigard Public Schools. Three first-grade teachers were trained in italic during a six-week period. Equal teacher training time was spent with three other teachers who volunteered their classes for the manuscript control group. Each of the six teachers had several years of teaching experience. It was decided that one sampling of student writing would be taken each year in January for objective evaluation, and a second sample would be taken in June for subjective evaluation. See Table I.

Until the final results are in, it will be impossible to begin forming conclusions. But it is possible to assess the educational usefulness of information gained along the way. For example, the record of each class performance of each letter has been of considerable interest to the teachers responsible for the children trying to learn to write. The results of phase one computer tally clearly indicate the relative difficulty that each criterion posed for each class and then, in phase two, relates the class performance to the other two classes in the group. For the first-grade italic teachers, the information gained has resulted in revisions of teaching techniques for this year and some revision in the format of the student worksheets. Changes were made in the techniques for teaching letter slope (the weakest performance of any criterion for all the classes). The teachers also met and planned new strategies for the first-grade instruction of one particularly difficult letter family: the a, d, g, and q. These letters had shown relatively high deviation rates in the first objective evaluation, and

each teacher had also noted difficulties at the time of instruction in a journal of instruction kept by each of them during the first year. The objective scores, combined with the subjective impressions of parents and teachers, provide a comprehensible and apprehensible base of evidence for curriculum directors responsible for program evaluation and selection.

*Table I. Results of Objective Evaluation Measurements
Made from Student Samples Taken in January 1972 and 1973*

The two evaluators are presented here as "A" and "B". The numbers listed under each judge represent their standard deviation average scores with an average of the average deviation rates listed in parenthesis.¹¹ The criteria are listed at the left. While evaluator "A" measured the traditional instruction classes, evaluator "B" measured the italic classes. Then they switched material to give each group a second measurement. The interjudge reliability for the standard deviation rates was determined by use of the Pearson Reliability Coefficient formula to be .986 for 1972 and .898 for 1973.

	<i>Traditional</i>		<i>Italic</i>		<i>Traditional</i>		<i>Italic</i>	
	N=59		N=81					
1972	A		B		B		A	
1. Letter angle	(+.2)	4.7	(-3.2)	5.5	(+.5)	4.3	(-2.9)	5.5
2. Length of letters	(+.3)	2.0	(+.1)	1.3	(+.1)	2.1	(+.3)	1.2
3. Spacing between letters	(+1.9)	3.0	(+.8)	2.3	(+1.9)	3.0	(+1.0)	2.2
4. Cartesian grid								
Vertical	(-.0)	1.4	(+.1)	.9	(-.1)	1.2	(+.1)	1.0
Horizontal	(+.4)	1.5	(-.0)	.7	(+.1)	.8	(-.1)	.9
1973	N=45		N=60					
Evaluators:	A		B		B		A	
1. Letter angle	(+1.4)	5.3	(-.7)	3.4	(+2.0)	4.5	(-1.5)	5.1
2. Length of letters	(+.0)	1.8	(+.2)	1.1	(-.3)	1.8	(+.2)	1.3
3. Spacing between letters	(+.9)	2.1	(+.3)	1.7	(+.2)	2.1	(+.3)	1.8
4. Cartesian grid								
Vertical	(+.3)	2.2	(+.0)	.8	(-.1)	1.5	(-.1)	.9
Horizontal	(+.3)	1.2	(-.0)	.5	(-.0)	.9	(+.1)	.5

Conclusion

As a process of evaluation, single objective measurements can be used to reliably pin-point the kind and severity of a writer's production deviations for each of the criteria: letter slope, space, scale, and shape. Computerized tally of results can provide necessary diagnostic detail to classroom teachers for the prescription of appropriate remedial practices. Summaries of average deviation rates and standard deviation rates can also be useful to administrators who are charged with program selection and evaluation.

The preliminary progress report of the Tigard School District research indicates that italic handwriting in the primary grades results in less severe handwriting deviations by the participants, particularly in the area of shape making. This is probably due to the elliptical quality of italic letters which also slant slightly to the right as a cursive system from the beginning of grade one. Although the average deviation rate is quite close for the two pilot groups of the study, the standard deviation rate for italic is significantly lower for the criteria with the exception of letter slope. Subjective evaluations, in the form of interviews of parents and teachers, have consistently endorsed the italic program. The parents have expressed aesthetic reasons and the teachers have consistently mentioned the elliptical quality of the letter shapes and the continuity of instruction inherent in the program.

During the third and final year of the pilot study, the speed of the two pilot groups will be evaluated as well as the other criteria. It was not considered to be a significant factor in the evaluation of the handwriting performances of first- and second-grade students.

1. Stanley Morison, *Principles of Typography* (Cambridge: Cambridge University Press, 1967), p. 7. "Roman" is the traditional name given to handwriting and type designs derived from the ancient Roman inscriptional capitals and the miniscule hands of the Italian Renaissance. The vast majority of books, periodicals and newspapers produced in our culture use "roman" type.

"The italic, the supplementary sloping type used by printers for the purposes of contrast and emphasis, is derived from a cursive variant of the revived Caroline letter and owes its simpler form to the tendency of the hand to seek the easier course and to avoid uneconomical pen-lifts." Alfred Fairbanks, *A Book of Scripts* (Baltimore: Penguin Books, 1968), p. 16.

Manuscript and the commercial cursives that are used for handwriting instruction in most public education programs today are directly descended from the roman models. The commercial cursive letter models descend to us from the Renaissance italic hand, modified significantly by interpretation in the engraving processes of the seventeenth and eighteenth centuries and adaptation to secretarial service in commercial situations of the eighteenth, nineteenth and twentieth centuries. Manuscript models were introduced to educators by Edward Johnston in 1913. He demonstrated them as skeletal models of the roman hands. Johnston did not propose the skeletal models for adoption in themselves and was not consulted when they were selected for teachers to use.

2. Alfred Fairbank, *The Story of Handwriting* (New York: Watson-Guption Publications, 1970), p. 75.

Edward Johnston, *Writing, Illuminating and Lettering* (1962 reprint; New York: Pitman Publishing Co., 1906), p. 203.

3. Morison, p. 6.

4. Fairbank, *A Book of Scripts*, p. 28.

5. Frank Freeman, "A New Handwriting Scale," *The Elementary School Journal* (January 1959), 219.

Leonard S. Feldt, "The Reliability of Measures of Handwriting Quality," *Journal of Educational Psychology*, No. 53 (1962), 239.

Luella C. Pressey and Sydney L. Pressey, "Analyses of Three Thousand Illegibilities in the Handwriting of Children and of Adults," *Educational Research Bulletin* (Sept. 28, 1927), pp. 270-273.

T. Ernest Newland, "An Analytical Study of the Development of Illegibilities in Handwriting from the Lower Grades to Adulthood," in *Remedial Teaching: Research and Comment*, ed. Wayne Otto and Karl Koenke (Boston: Houghton Mifflin Co., 1969) pp. 240-247.

Leslie Quant, "Factors Affecting the Legibility of Handwriting," in *Remedial Teaching: Research and Comment*, ed. Wayne Otto and Karl Koenke (Boston: Houghton Mifflin Co., 1969) pp. 270-284.

6. Herrick and Erlebacher, "The Evaluation of Legibility in Handwriting," in *New Horizons for Research in Handwriting*, ed. Virgil E. Herrick (Madison: The University of Wisconsin Press, 1963), p. 212.

7. Quant, *op cit*.

8. Fairbank, *A Book of Scripts*, p. 28.

9. Johnston, p. 238 (footnote). When the bottom half of the word is covered it usually can still be read, but not when the top half is covered.

10. The various criticisms of manuscript and cursive writing systems are gathered from several authors and from personal discussions with primary grade teachers. It is my impression that third grade teachers in particular, have a dread of taking children into commercial cursive from manuscript.

Frank Freeman, "Evaluation of Manuscript Writing," *Elementary School Journal*, (February 1936), 454.

J. De V. Heese, "Manuscript Writing," *Journal of Educational Research*, XL (November 1946), 165.

Fairbank, *A Book of Scripts*, p. 25.

Lloyd Reynolds, "Italic Handwriting," a privately published essay (1968) available through the Western American Branch of the Society of Italic Handwriting (7423 S.E. 31, Portland, Oregon).

11. While the average deviation rates of each criterion compares closely for both kinds of handwriting (within 2–3 degrees for letter slope and less than 1 millimetre for the other criteria), the incidents of deviation that were averaged to make up the traditional scores occurred on a much broader range (standard deviation rate), indicating that the traditional handwriting group performed errors that were more serious, both in excess (plus scores) and defect (minus scores) to make up the average deviation rate.

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