



CERLI[®]

The Development of Modern Reading and Writing in Child and Adolescent Learning





THE DEVELOPMENT OF MODERN READING AND WRITING IN CHILD AND ADOLESCENT LEARNING

CENTER FOR EDUCATIONAL RESEARCH, LEARNING & INNOVATION

ABSTRACT

Reading and writing are connected to learning at the neural level, as illustrated by the way handwriting activates brain networks associated with memory, attention, and creativity, and by how these skills affect reading comprehension and written expression.

In the digital age, however, the development of these abilities is being challenged by the integration of technology into the classroom. This report examines the importance of handwriting and cursive in education and their relationship with brain development, while proposing instructional strategies for effectively integrating handwriting into contemporary school curricula and balancing tradition with digitalization.

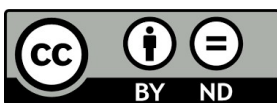


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Introduction

If you were born in the last century or at the beginning of this one, you will remember that reading and writing were always central to education in the early grades. It was considered extremely important for children to learn to read, write, and develop proficient handwriting in both print and cursive. Today, however, this has changed.

One direct consequence of the integration of technology into the classroom, which we have always strongly advocated and promoted, has been a diminished appreciation of the true importance of these skills. As the use of electronic devices such as computers and cell phones has been favored, the focus has shifted toward typing and the ability to produce text as quickly as possible. Although this is a positive development in the modern world, we must not lose sight of the fact that reading, writing, and handwriting skills serve more than one purpose.

These were never merely aesthetic exercises; their foundations lie in cognition, brain development, sequential thinking, and a hundred other important aspects of human development. This seemingly minor shift in accepted curricular practice, while consistent with the usual patterns of educational change, has had highly significant negative effects that institutions have ignored.

At CERLI, we value technology as a tool for social and educational transformation. We have developed and refined multiple curricula that integrate technology into education, prioritizing the academic and professional interests of today's society. But we also recognize the importance of the human and developmental aspects of education and their role in human growth.



Those involved in education must ensure that curricular reforms strike a sound, evidence-based balance. This entails a responsibility to recognize whether a particular innovation truly contributes to students' overall development or, instead, sacrifices fundamental cognitive and human dimensions for the appearance of a more technologically advanced classroom.

In this sense, relegating analog reading and writing skills to a secondary role amounts to dismantling an entire process grounded in psychological principles far more important than is generally acknowledged. For this reason, we will argue that genuine innovation in modern education is defined by a balance between what the labor market demands and what history and science have shown to have substantial human and educational value.

If education aims to prepare citizens who can think critically, be creative, and adapt to rapidly changing circumstances, we must accept that this is possible only when technological innovation strengthens our foundations instead of erasing them, supporting a much deeper and more meaningful learning process. As always, we are delighted to contribute to this transformation by providing guidance and sharing knowledge about these enduring principles and how we can build on them.

From Traditional to Digital

Reading and writing have always been fundamental pillars of early education because they rest on a set of skills whose importance extends beyond the individual, laying the foundation for how we think, communicate, and participate in society. Their significance is such that we even use them to measure a country's development as a whole. When we discuss literacy rates, we are referring to a clear indicator of a country's capacity to build citizenship, agency, knowledge, and equity.

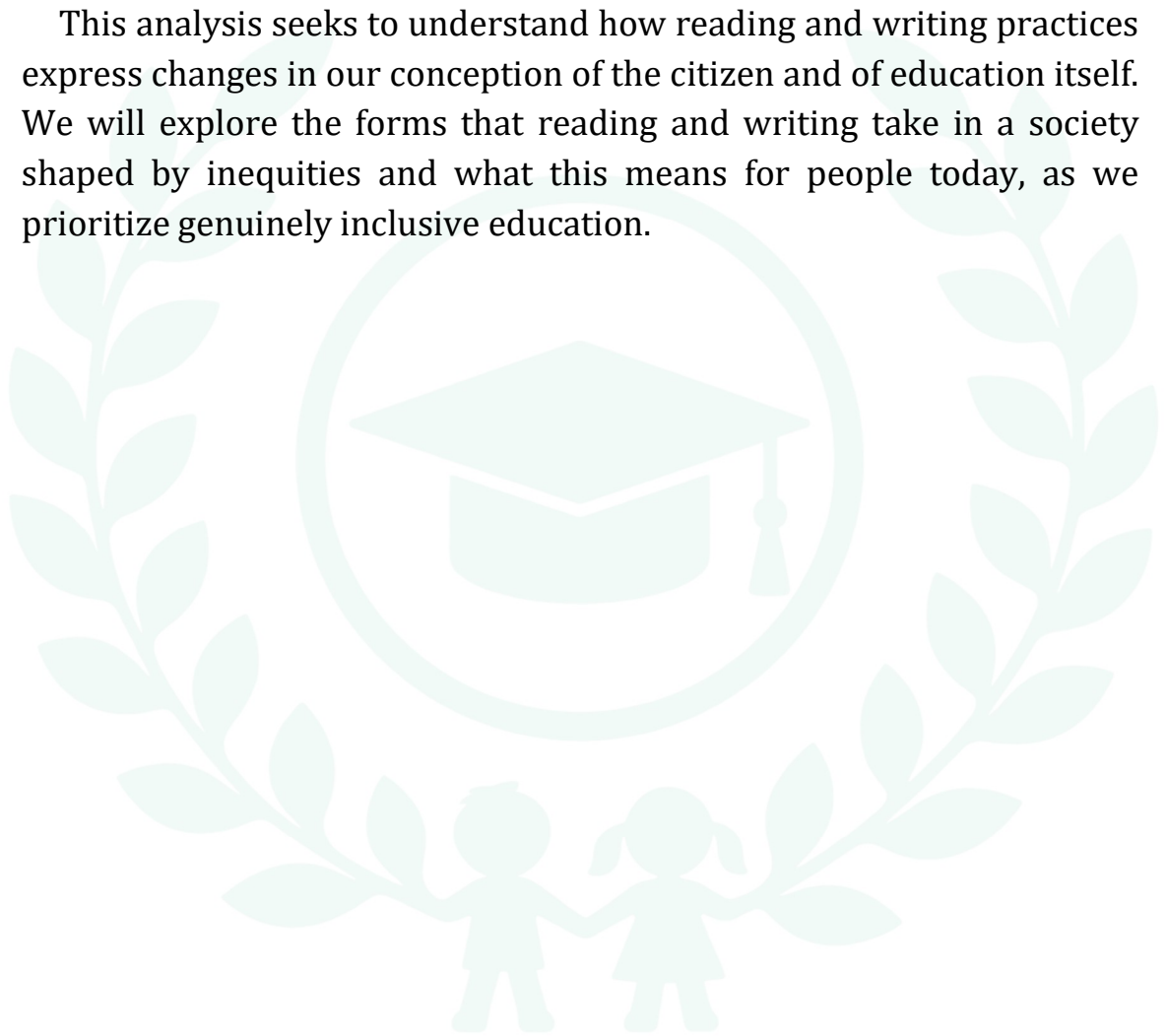
History shows, however, that reading and writing have not always been understood in the same way. What we now consider an essential, natural, and universal practice was, at other points in our history, a restricted tool, a privilege for the few, and even an instrument of power. Clearly, then, people have not always read and written for the same purposes or under the same ideals. In different periods, learning to read and write meant very different things: an instrumental skill for recordkeeping and administration, an act of intellectual emancipation, or a form of cultural resistance.

Each era brought its own understanding of knowledge to reading and writing. Understanding this historical evolution allows us to recognize that reading and writing are neither static nor purely technical. They are a profoundly human phenomenon whose teaching responds to contexts, interests, and paradigms that determine what is considered worth learning and who has the right to learn it.

From a twenty-first-century perspective, we can reinterpret a context entirely different from the one we see today and find answers to the

questions we ask about modern education. Before exploring modern reading and writing and the many challenges they present in education, we will therefore examine how they have changed over time. In the following sections, we will review how these transformations have shaped different paradigms of reading and writing instruction, from their roots in traditional models to their expansion in today's digital world.

This analysis seeks to understand how reading and writing practices express changes in our conception of the citizen and of education itself. We will explore the forms that reading and writing take in a society shaped by inequities and what this means for people today, as we prioritize genuinely inclusive education.



The Ancient World

For centuries, in ancient civilizations such as Mesopotamia and Egypt, reading and writing were skills associated with prestigious and important social functions. Those who learned to read and write went on to occupy highly respected roles such as scribes or accountants. These professions were very well paid and could be learned only in monasteries or scribal schools, which were reserved exclusively for society's highest elites.

The learning method was uniform, rudimentary, and primitive: students memorized symbols and reproduced them repeatedly on tablets made from different materials depending on the civilization ¹, then recited their sounds aloud. Rather than a body of knowledge, reading and writing were a technique learned through memorization and repetition. Whether this means that the process cannot actually be considered genuine learning remains a subject of debate. Still, because the aim was for only the few people who would hold important positions to learn these skills, one could say that it fulfilled its purpose.

The writing used in this period was largely logographic and phonographic, meaning that it consisted of symbols rather than letters. For example, classical Mesopotamian writing is known as “cuneiform,” and each sign represented a word, a syllable, or even a concept. It emerged because the Sumerians needed a way to record commercial transactions, agricultural inventories, and certain administrative matters. They therefore sought a form of writing that was simple,

¹ Writing media varied by civilization and purpose. Papyrus predominated in Egypt; clay tablets were common in Mesopotamia; Greece used papyrus and wax tablets, among other media; and papyrus and wax tablets were common in Rome.

without excessive detail, and easy to inscribe in wet clay, a material that was inexpensive, malleable, and durable once dry.

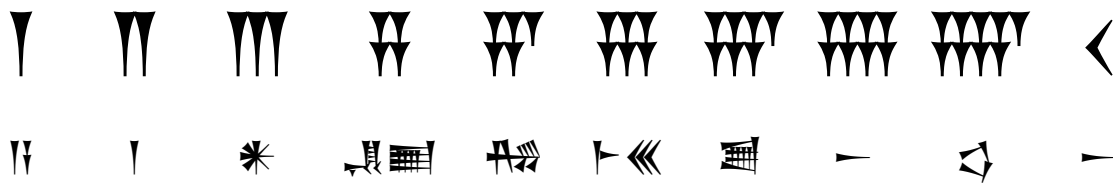


Figure 1: Approximate examples of cuneiform symbols. The top row, from left to right, contains the numbers one through ten. The bottom row, in the same direction, contains the ten common symbols, in this order: “water,” “earth/place,” “god,” “king,” “box/container,” “barrel of grain,” “sheep,” “bird,” “sun,” and “moon.”

Their distinctive shape came from the tool used to inscribe them: a reed sharpened into a wedge, known as a “calamus,” which in turn gives this form of writing its present-day name ². This way of writing made certain strokes, such as the number one and the symbol for “earth,” or the concepts “bird” and “moon,” virtually identical. Scribes had to distinguish them through context, so their learning involved reading comprehension beyond a simple writing technique.

In Egypt, the famous hieroglyphs were similar, but with some differences. They are written without spaces between words and without any punctuation marks. They can also be written either horizontally or vertically. To determine where a hieroglyphic text begins, the reader looks at the direction the symbols face: if they face left, for example, we begin reading from left to right. In vertical writing, their direction indicates the starting point, and the text is always read from top to bottom.

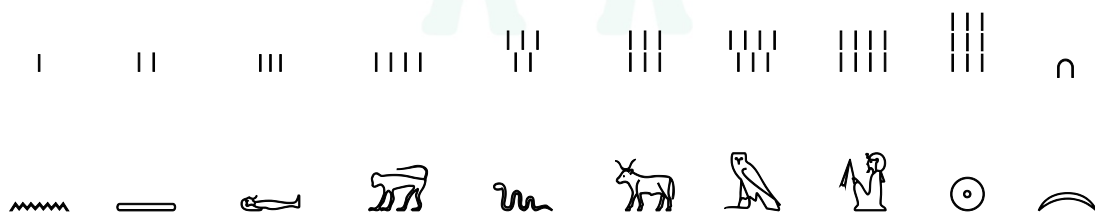


Figure 2: An approximate example of Egyptian hieroglyphic writing, based on Gardiner's list. The first row, from left to right, shows the numbers one through ten, while the second row shows the following concepts: “water,” “earth,” “dead,” “monkey,” “snake,” “bull,” “owl,” “king,” “sun,” and “moon.”

² “Cuneiform” comes from the Latin “cuneus,” meaning wedge.

Compared with cuneiform writing, we might consider hieroglyphs more ambiguous but also more intuitive, since they are much more pictographic. For example, whereas “day” was represented in cuneiform by the symbol , in Egyptian hieroglyphs the concept of “day” was represented by the solar disk itself (). This difference reflects their social purposes: cuneiform emerged as a tool for accounting and administration, whereas hieroglyphs had a more ritual and cultural foundation.

The technical difference between the two lies largely in the difficulty of both inscription and comprehension; cuneiform was much more systematic and faster once learned. In fact, in daily life, hieroglyphs were divided into two forms: hieratic, used in more professional settings, and demotic, a simplified variant for everyday use. Hieroglyphs also require a degree of artistic talent to distinguish certain animals and symbols, so ambiguity in scribes' work could make texts harder to understand.

Hieroglyphs had a major influence on other ancient writing systems. Although it might seem that all civilizations followed the path of logography, some took a different direction. One example is the North Semitic alphabet used by the peoples of the Levant during the first half of the first millennium BC.

This alphabet operated through a technique known as “acrophony,” which consists of taking a pictographic symbol, such as a hieroglyph, and turning it into a phonetic symbol in its own right. The sound of the first consonant in the word represented by the image is used to turn the symbol into a phonetic grapheme that no longer stands for the original concept, but for a sound. For example, if we take the hieroglyphic symbol for the sun (), pronounced “ra,” we extract the sound of the first consonant (/r/), and the original symbol now represents that sound rather than the concept of the sun.

It sounds complex, but it is extremely useful. Using this technique and starting from an established pictographic system, we can create an alphabet that encompasses all the concepts already defined without requiring a separate image to be learned for every word or concept. A

small set of letters can be used to write every word, without depending on varying interpretations caused by a scribe's lack of technical skill. As if this were not enough, following established phonetic rules allows translation between languages, which encouraged the creation of new alphabets.

To create their alphabet, the Phoenicians combined acrophony with a type of writing known as “consonantal”: it consisted of twenty-two distinct graphemes, all of them consonants. The reader “inferred” the vowels from context ³. This technique relied on the very stable consonantal root structure of Semitic languages, such as Hebrew, which makes it possible to infer the missing vowels from the contextual information in a sentence.

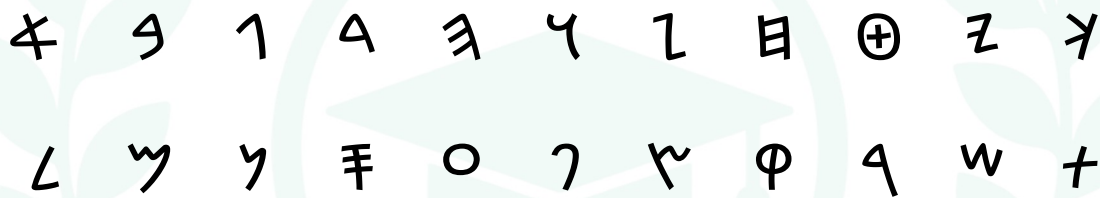


Figure 3: An illustrative approximation of the 22 letters of the Phoenician alphabet, in order.

It was written predominantly from right to left, and its simplicity appealed to maritime traders in the Mediterranean. Learning Phoenician writing was essential for the new commercial activities beginning to develop, in which there was an urgent need to unify the region's different languages. Although its simplicity compared with pictograms was undeniable, its entirely consonantal structure still prevented it from being completely straightforward to learn.

This problem would soon be resolved, as Mediterranean cultures developed interesting variants from Phoenician. In Greece, where people were revolutionary by nature, an alphabet with 24 letters in total

³ The word “inferred” appears in quotation marks because those vowels did not actually exist. All the information could be inferred from the context in which the sentence was written. The absence of graphemes representing vowels simply made the system more difficult to learn, but the information conveyed remained the same.

was used: seven vowels (Alpha, Epsilon, Eta, Iota, Omicron, Upsilon, and Omega) and seventeen consonants.

Α	Β	Γ	Δ	Ε	Ζ	Η	Θ	Ι	Κ	Λ	Μ
Ν	Ξ	Ο	Π	Ρ	Σ	Τ	Υ	Φ	Χ	Ψ	Ω
α	β	γ	δ	ε	ζ	η	θ	ι	κ	λ	μ
ν	ξ	ο	π	ρ	σ	τ	υ	φ	χ	ψ	ω

Figure 4: The 24 letters of the Greek alphabet. Rows one and two, read from left to right, show the uppercase letters, while rows three and four, in the same direction, show their lowercase counterparts.

In Greek, vowels formed the basis of words and verb tenses. Without a consonantal structure as fixed as Hebrew's, it was very difficult to infer them from context alone. Including vowels as graphemes in the alphabet was therefore essential, since they supplied the context within a sentence, making the alphabet much easier to use than Phoenician.

This change would provide the foundation for the other alphabets that survive today, so we might say that this was the point at which the purpose of language became more communicative than administrative. Yet because education remained confined to small social groups, we cannot speak of Greek reading and writing as an educational phenomenon. The education system still served no function beyond the strictly professional, and a long time would pass before it began to be seen as a means of human development.

The Middle Ages

During this period, the Catholic Church gained considerable power over people's lives, making monasteries and cathedral schools the main settings for learning to read and write. Literacy was deeply rooted in faith, since it was seen as the means of understanding the Bible, an essential key to drawing closer to God. Unlike in the Ancient World, however, there was a strong interest in preserving sacred texts. The study of Gothic calligraphy was therefore particularly prominent, with the aim of preserving both content and style.

In the initial stages, students memorized the Latin alphabet and reproduced individual letters on tablets or small pieces of parchment, in an exercise combining fine motor skills with spiritual discipline. As they progressed, they began studying grammar through authors such as Donato or Pisciano, whom the Catholic Church regarded as pillars of medieval teaching. Grammar served as a means of accessing liturgical texts, which were central to the daily lives of the clergy.

Copying texts was the central practice. Under a teacher's supervision, apprentices transcribed biblical passages or psalms that they also had to memorize and recite. Students were required to copy a model of handwriting, known as an exemplar, precisely until they could make the strokes automatic and faithfully reproduce the form and rhythm of the lettering. In this way, writing became an exercise in obedience, patience, and attention, virtues highly valued in monastic culture.

At the end of the learning process, students worked together in a place known as a “scriptorium” ⁴ to produce manuscripts. Each had a

⁴ Scriptorium translates directly as “place for writing,” although authors often refer to it as a “scribes' workshop.”

specific task: some copied the text, others rubricated it with red lettering, others added ornamental details to the initials, and a final group handled the binding. Every step demanded great precision and collaboration among peers, who thereby demonstrated their technical, linguistic, and aesthetic skills.

The choice of calligraphy, we should emphasize, was far from arbitrary. What is known as “Gothic calligraphy” has a severe, solemn appearance that commanded respect and conveyed intellectual rigor. This aligned perfectly with the scholastic ideals of the period, when the Church held political power and its writings had to represent its status appropriately.

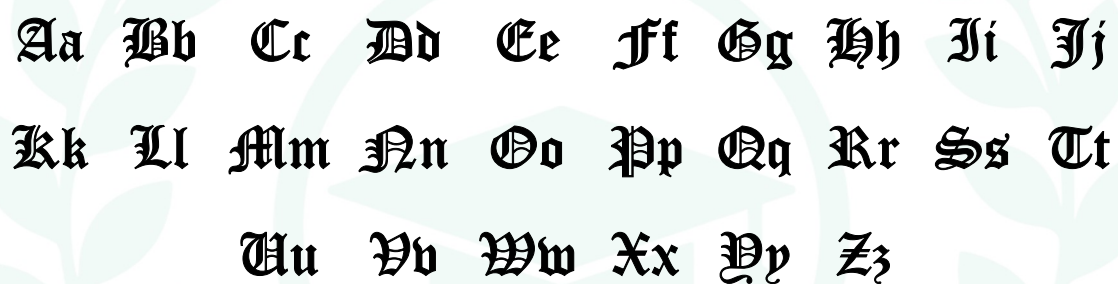


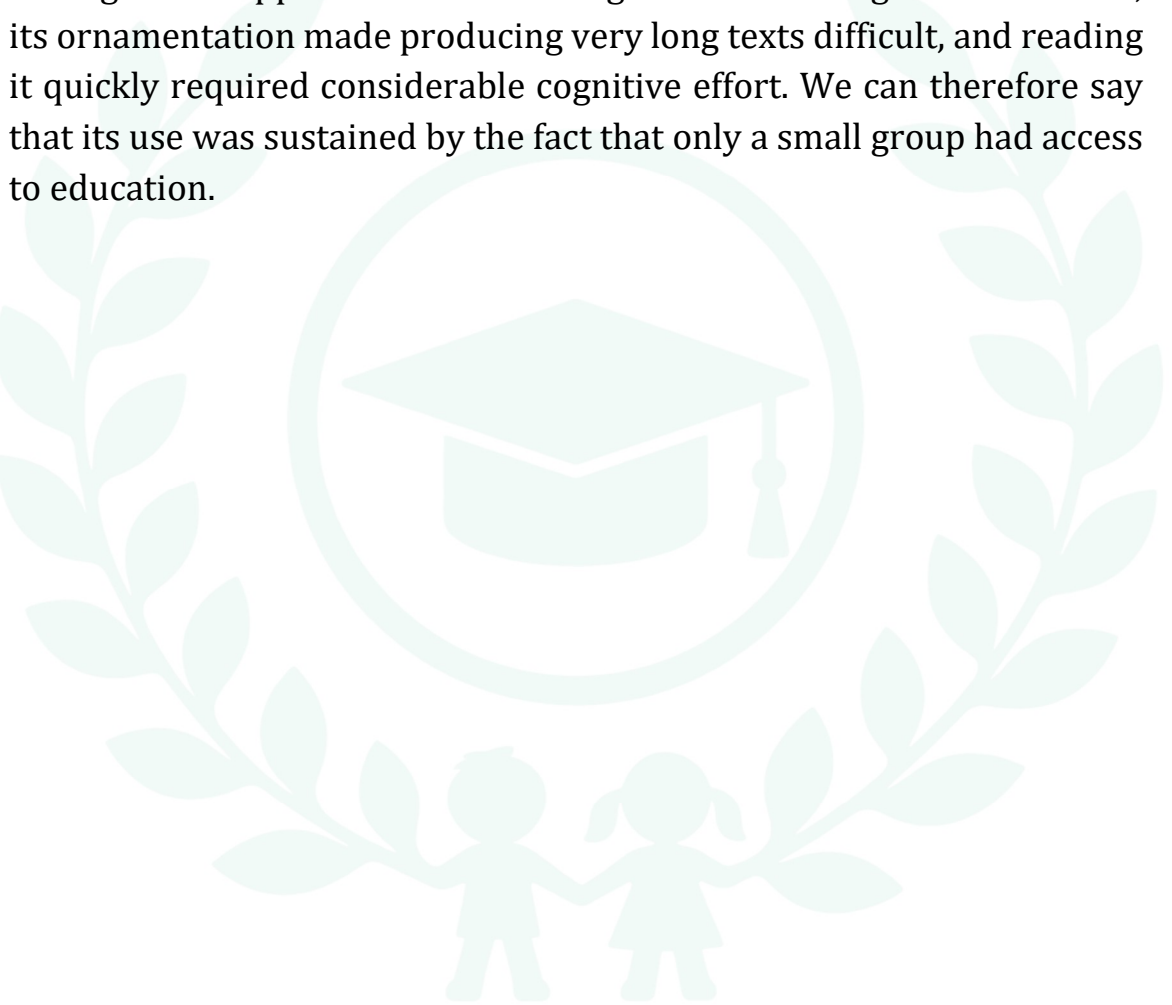
Figure 5: An approximate example of medieval Gothic calligraphy, showing its uppercase and lowercase forms of the Roman alphabet.

From an economic perspective, this choice also made considerable sense. Gothic calligraphy was extremely useful and efficient because parchment was very expensive. Gothic letters allowed a large amount of text to fit into less space, producing a visually uniform text that supported readability. In education, the rise of universities created a demand for dense, readily readable manuals that could bring all the information together. University students saw this script as a mark of prestige: using it correctly was equivalent to belonging to an intellectual “elite.”

In addition to all of this, although the letters may appear complex because of their angular structure, the calligraphic foundation of the Gothic style consists of what are known as “minims.” These are straight, parallel strokes, and because all Gothic letters are constructed by

combining them, only the most basic strokes need to be memorized⁵. With sufficient repetition, learning Gothic calligraphy becomes relatively straightforward, and the simplicity of its strokes makes it easy to automate the process and develop writing speed.

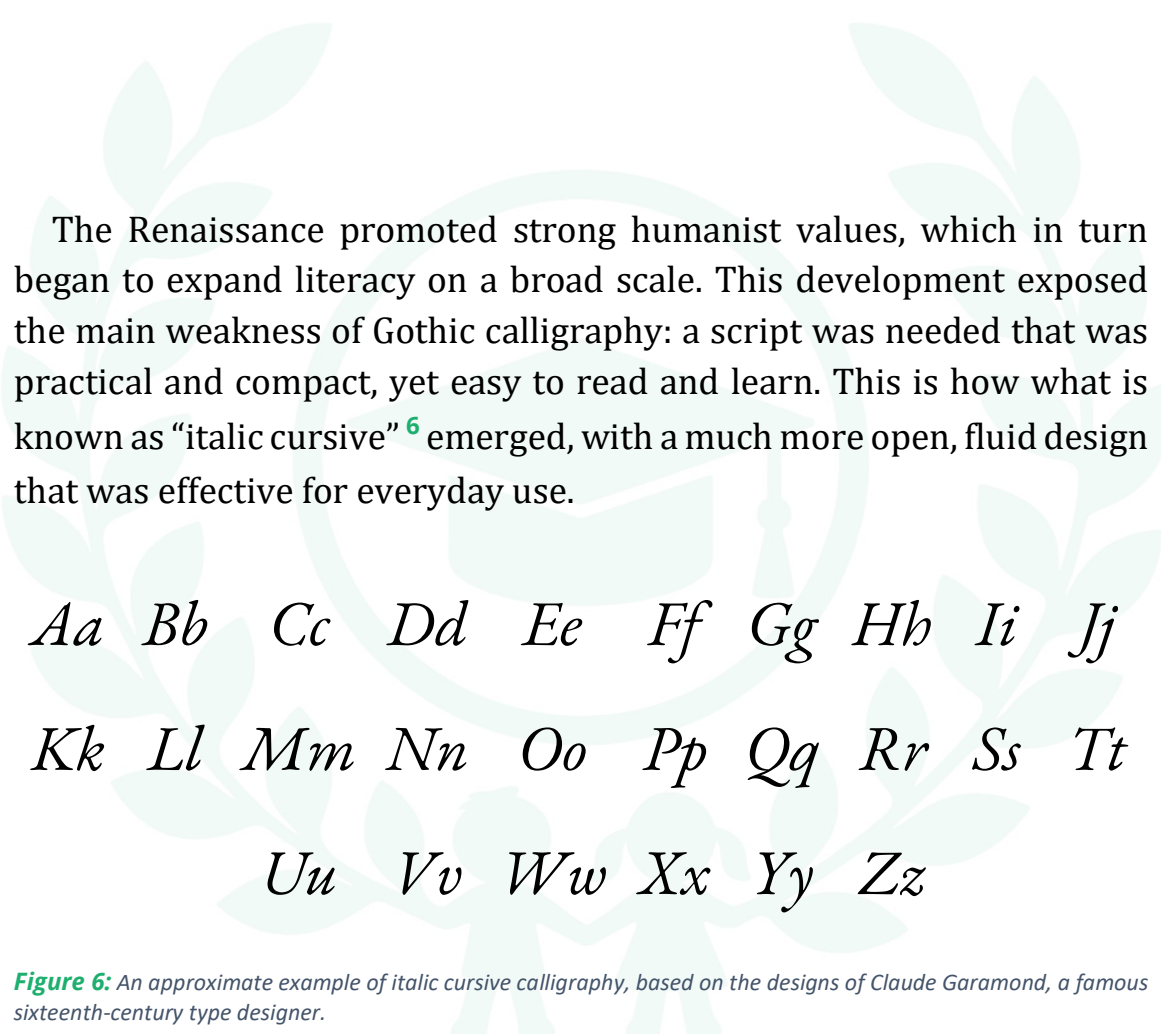
Books of great historical importance to universities, such as the Gutenberg Bible, were written using variants of this script. Its mere presence in a manuscript automatically gave it an intellectual and distinguished appearance. Yet although it was striking and consistent, its ornamentation made producing very long texts difficult, and reading it quickly required considerable cognitive effort. We can therefore say that its use was sustained by the fact that only a small group had access to education.



⁵ Because minims are drawn at consistent angles and at the same height, the resulting letters always remain horizontally aligned. If one stroke deviates, the next minim simply needs to be adjusted to maintain visual consistency within the word. As a result, texts written in this period were extremely similar and visually consistent, even when produced by different scribes.

The Renaissance and the Early Modern Period

The Renaissance promoted strong humanist values, which in turn began to expand literacy on a broad scale. This development exposed the main weakness of Gothic calligraphy: a script was needed that was practical and compact, yet easy to read and learn. This is how what is known as “italic cursive”⁶ emerged, with a much more open, fluid design that was effective for everyday use.



Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 6: An approximate example of italic cursive calligraphy, based on the designs of Claude Garamond, a famous sixteenth-century type designer.

Cursive offered countless advantages because it required simpler, more continuous movements, making them easier to automate and reducing the time needed to write a word. Its visual clarity also made it easy to read, and its compactness meant that it required no more paper

⁶ As its name suggests, it was used primarily in Italian manuscripts of the fifteenth and sixteenth centuries.

than the Gothic style. This allowed it to be used in educational manuals that students could use without difficulty.

This was very useful in education: its visual consistency made it easy to read, so teachers had no difficulty marking students' work. Although precise experimental verification was not feasible at the time, cursive in fact strongly supported the development of fine motor skills and reading comprehension, which was very important as access to education expanded.

But as we have seen in every other era of human history, nothing lasts forever. Although italic cursive was easy to learn and allowed long texts to be written quickly, it represented a dramatic departure from ornate Gothic scripts. The English wanted something that could be standardized more readily and had an elegant appearance, while remaining easy to learn and efficient to write. The simplicity of italic was therefore set aside in favor of a version known as “English cursive.”

This variant was based on a style of calligraphy known as “round hand,” developed in England in the late sixteenth century. Although it may at first appear much more complex than italic, this is not necessarily the case. Round hand is formed through regular contours in the hand's movement that do not vary greatly between uppercase and lowercase letters, and its connections between letters are more consistent and predictable. Together, these features made it relatively easy to learn, refine, and write quickly in this script.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 7: An approximate example of English round hand calligraphy.

With the growth of colonial trade in the eighteenth and nineteenth centuries, however, the English also sought an elegant, cultivated, and formal script that remained simple and efficient to write, but had more pronounced flourishes that would not produce significant errors or differences across the surfaces on which they were engraved. This gave rise to the variant known as “copperplate”⁷, which quickly became the visual standard for formal calligraphy in that period.

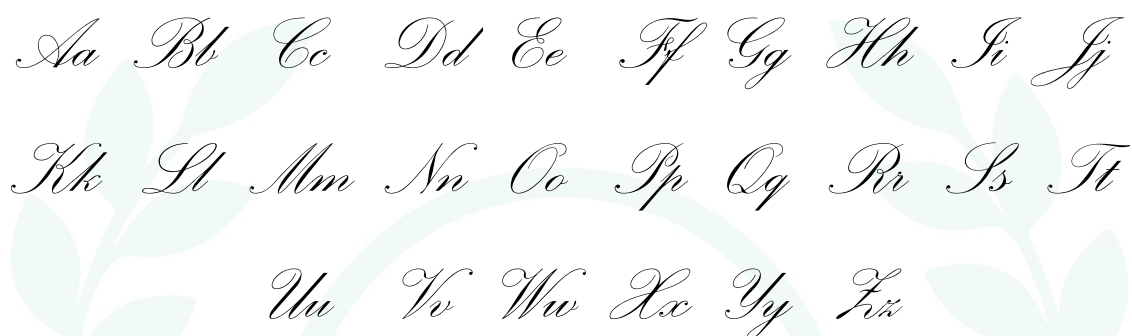


Figure 8: An approximate example of “Copperplate” English cursive.

English cursive, particularly the copperplate variant, remains part of many curricula around the world in the early school years. Its beauty, legibility, and simplicity allowed students to develop neat, formal handwriting without relying on complicated artistic techniques. Even so, as more and more students entered the education system, a different style of handwriting began to provide their first introduction to reading and writing.

We are referring, of course, to the very familiar “print handwriting.” As its name suggests, it originated in the lettering used primarily to print books, magazines, and newspapers. These required exact precision from one copy to the next, which was very difficult to achieve with a script that required some skill to keep uniform and legible. Errors would be inevitable, so while cursive remained the standard for more personal documents, a new style was needed for printed materials.

⁷ It was called “copperplate” because copper was the material on which printing plates were engraved. Owing to their characteristics, the letters reproduced by these plates had high contrast, very fine strokes, and highly refined flourishes.

With much straighter forms and a significant distinction between uppercase and lowercase letters, print quickly became everyone's favorite. Its uppercase forms were drawn from Roman epigraphy, and its lowercase forms from Carolingian and humanist scripts. This made them perfectly reproducible on a large scale while reducing the cognitive effort involved in reading.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 9: An example of print handwriting in uppercase and lowercase, based on Claude Garamond's sixteenth-century styles.

Over time, slightly simplified variants of this lettering style even began to emerge, making individual letters easier to distinguish. This was essential for the printing process, but it also gained considerable traction because of its readability, becoming a standard for reading.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 10: An example of print handwriting in uppercase and lowercase, based on Claude Garamond's sixteenth-century styles.

As always, education had to adapt to this reality. Although cursive remained fundamental to children's and adolescents' development and learning, it was impossible to keep them away from print when

everything around them used it ⁸. The change was not easy: cursive had many practical and aesthetic justifications, was considered more elegant and disciplined, and appeared in the vast majority of existing handwritten documents and books.

Furthermore, by the twentieth century, early studies in educational psychology and graphology showed fine motor development associated with learning cursive, as well as greater long-term writing speed due to the continuity between letters, compared with print handwriting. Yet despite the passage of time and close attention to detail, no study has established with complete clarity whether there is a substantial difference between learning the two styles and their impact on the development of a child's mind.

Some things are evident: learning to read and write in cursive is more complex and engages our brains much more. There is evidence that cursive prevents the train of thought we seek to express in writing from being constantly interrupted, because it allows us to write whole words without lifting the pencil. Cursive also avoids rotation errors, which arise because certain lowercase print letters are exact mirror images of others ⁹.

However, these slight improvements in fine motor skills and early reading and writing were the only effects of cursive that have been demonstrated consistently. Nor can we deny that print handwriting has advantages of its own. From an inclusion perspective, this style of writing makes reading significantly easier. When writing, however, maintaining a standard structure, such as consistent spacing between letters or similar density across lines, becomes a complex task.

What seemed at the time to be a fundamental academic debate would soon pale in comparison with the arrival of technology. No one imagined

⁸ As an interesting aside, print handwriting was the last major handwriting style to gain broad curricular acceptance before the digital age.

⁹ This can be seen in cases such as “p” and “q,” or “b” and “d.” Students who struggle with reading and writing find these letters particularly difficult, which leads specialists to favor other typefaces.

that, within just a few years, the debate about reading and writing would concern methods rather than handwriting styles. Let us explore this further.



The Mechanical Age

Curricula had already yielded a little ground with the formal inclusion of print handwriting. It seemed that we were moving toward an established, widely accepted system of reading and writing by hand, until everything changed. As technology entered our lives, writing was no longer necessarily done primarily by hand. Although we associate technology with computers, in this case the debate is much older.

When the first typewriters were created back in the nineteenth century, a new dimension entered the educational discussion about handwriting: typing. This encompasses the techniques and skills that allow people to write quickly and accurately using a keyboard. It requires developing muscle memory for the correct key positions and internalizing finger placement to avoid looking at the keyboard while writing.

Typing resolves the problems of legibility and similarity between letters at their root, since everything written on a typewriter would use the same lettering, which would come to be called a “font,” and would always retain the same characteristics, regardless of who was writing. The main difference between writers would therefore be the speed at which they could type and their ability to avoid errors, which on a typewriter would be impossible to erase.

The lettering used on typewriters in the late nineteenth century consisted of a monospaced font. This means that each character occupied the same horizontal width, arranging letters and numbers compactly on the page. The forms were simple, with some ornamental details resembling Roman typography, but with a degree of horizontal uniformity. The aim was to produce readily readable, standardized

texts, although their uniformity varied because of the characteristics of the internal mechanisms.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 11: An example of an early typewriter font. It has the texture and serifs typical of the late nineteenth century.

Later, in the twentieth century, this lettering was replaced by what we now know as “Courier.” Designed by Howard Kettler in 1955 for IBM, it was inspired by early typewriters. It was simpler and more minimalist than its predecessors, much more legible and modern, and optimized for mechanical and electric typewriters. It would later form the basis for uniform typographic printing and source code.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 12: An example of the “Courier” font, adapted for modern screens while remaining faithful to its original appearance.

Typing quickly became the primary means of professional writing, considerably expanding employment opportunities for anyone seeking work involving writing, according to their typing skills. In film, for example, the Courier typeface became the standard for screenwriting and remains so today. Why? When monospaced Courier is used at 12 pt, following conventions such as prescribed margins and double spacing,

each page of a screenplay corresponds to approximately one minute of footage ¹⁰.

The debate was set: should students develop greater proficiency in handwriting or typing? The main centers of educational thought in the late nineteenth and early twentieth centuries decided that typing should be included in educational programs. Out of simple caution, specialized courses were initially introduced as optional subjects for students, but they were soon incorporated into secondary and technical curricula.

Although this raised questions within the educational community, studies supporting handwriting, together with the fact that it remained the main form of written communication in everyday life, meant that replacing it with typing did not even need to be considered. Handwriting was still regarded as essential to students' intellectual and social development, giving it particular weight in curricular decisions.

Yet one final revolution remained before technology swept everything aside. The new computing systems, in other words, the first computers, were anything but simple. They occupied entire university basements, required teams of specialists to operate them, and were far from having any useful application in everyday homes. Still, they held a latent promise: the possibility of transforming how information was processed, stored, and transmitted.

These early computers required a new kind of lettering. They used dot-matrix, drum, or line printers, which could not accurately reproduce typewriter typography. This gave rise to early technical monospaced typefaces such as OCR-A and OCR-B, designed so that the optical character readers of the time could distinguish their characters easily.

¹⁰ Although this is an approximation, since certain rapid exchanges or scenes without dialogue may not follow the ratio of one page per minute, it remains a useful statistical average in practice, giving screenwriters a fairly accurate sense of how much screen time the final product will represent, long before filming even begins.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj Kk Ll Mm
 Nn Oo Pp Qq Rr Ss Tt Uu Vv Ww Xx Yy Zz

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj Kk Ll Mm
 Nn Oo Pp Qq Rr Ss Tt Uu Vv Ww Xx Yy Zz

Figure 13: The OCR-A (top) and OCR-B (bottom) fonts. Created in 1966 and 1968, respectively, both by Adrian Frutiger.

Meanwhile, cathode-ray tube displays and green-phosphor terminals had very low resolution. Characters therefore needed to be simple and perfectly aligned so they could be rendered easily. This led IBM to create its “IBM-3270” terminal font for internal use: entirely geometric, without ornamentation, and designed to be perfectly legible at low resolution.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
 Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
 Uu Vv Ww Xx Yy Zz

Figure 14: The IBM-3270 font, created internally by IBM in 1970 for its 3270 series terminals. Well known for its retro technological appearance.

Technology had already established a place in business, professional work, and higher education. It had reached a pivotal point for the future development of devices that would be truly useful in everyday life, but one small step was still needed before the great leap: simplicity. In the 1980s, the first desktop computers began to appear in homes, creating a need for a new range of lettering styles. Let us see how this unfolded.

The Digital Age

The arrival of electronic devices was a pivotal moment in history: an unparalleled milestone that revolutionized every area of our lives and reached into the very depths of what we consider human. But let us not get ahead of ourselves; we will continue the historical analysis we have developed so far. We are in the late twentieth century, and as the new millennium arrived, desktop computers became part of the home.

A new need began to take shape in the offices of the first technology giants. Earlier operating systems were too rudimentary, and although professionals and enthusiasts found them useful and fascinating, they did not appeal to the general public. One example is the famous MS-DOS, developed by Microsoft in its early years. It was an entirely text-based system without graphics, displaying only command lines on screen in a fixed monospaced typeface called IBM CGA/MDA. Although it is now remembered as iconic, it was too rigid for the great technological revolution of the time.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 15: An approximate example of the IBM CGA/MDA font. Used in early DOS operating systems.

Apple, also in its early years, took a radically different path. In 1984, it launched “Macintosh,” a personal computer for the mass market with a graphical user interface. This meant windows, icons, and interactive menus, which required a new typeface to make the operating system

intuitive for users. Digital graphic designer Susan Kare entered the picture here, tasked with creating the “Chicago” typeface.

This was a sans serif font with a square appearance, optimized for the pixels of a screen approximately nine inches in size, at a resolution of just 72 dpi ¹¹. Quite extraordinary! Its appearance was functional yet friendly, with thick, pronounced strokes that made all its characters distinguishable even at such a low resolution. The Macintosh was a success, and this typeface became a foundation of computing in the 1980s.

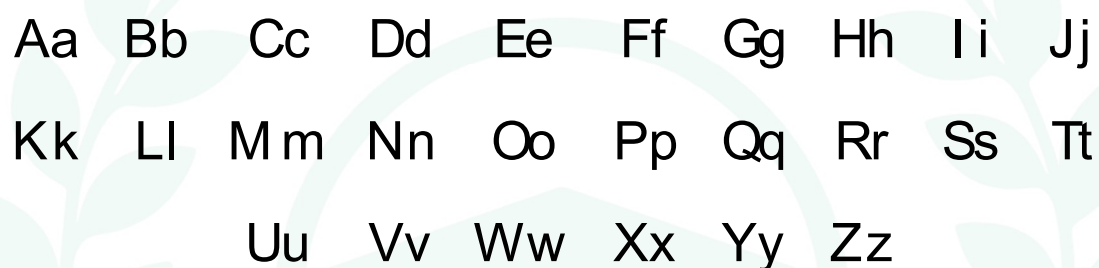


Figure 16: An approximate example of the Chicago font. Used in the first Apple Macintosh desktop computers.

Although MS-DOS dominated the traditional computer market, Microsoft decided to follow its competitor into graphical operating systems. With this in mind, the first version of Windows 1.0 was released in 1985. Although it was still more of a graphical interpreter for DOS than an operating system in its own right, it included functions that required a font users could readily understand. This gave rise to the famous “System,” designed specifically for low-resolution VGA environments.

¹¹ For those unfamiliar with display technology, older monitors were similar in size to today's tablets, but with an almost square aspect ratio (4:3). The abbreviation dpi (dots per inch), refers to the number of pixels that fit within each inch of a screen. A 72 dpi screen has low resolution, making the pixels large and visible. This makes letter design difficult, because each character had to be “drawn” on a very small grid. If a letter was too thin or contained too much detail, it would become distorted and its characters could no longer be distinguished correctly.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 17: An approximate example of the System font, used in the first version of Windows 1.0.

From this point onward, technology continued to advance. With the arrival of the twenty-first century, older CRT (cathode-ray tube) screens began to be replaced by new LCD and LED displays, which offered much higher resolutions. This was a significant change: digital typography stopped imitating print formats and began to operate by its own rules.

Every pixel counts, and designers can be much more creative in how they render content and use space on screens no longer constrained by size and resolution. Computers also became just one of the many electronic devices found in a home, requiring new typefaces to adapt and scale to different formats.

By the end of the century, this could already be seen in the first typefaces designed 100% for use in a digital environment. Designers such as Matthew Carter, in 1996, created some of the most iconic fonts, which remain in use today: “Georgia” and “Verdana.”

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 18: The “Georgia” (top) and “Verdana” (bottom) fonts, both created by Matthew Carter in 1996.

From here, each company's own ecosystem began to make its typefaces something very distinctive. In a sense, each font represented the company's identity, and users would recognize it easily. Although their designs differ slightly, they all share common goals: uniformity, legibility, and adaptability across multiple devices. Today, the font is seen as a fundamental, central part of the user experience.

To conclude this section of the report, we have chosen to show you the typefaces used by today's leading technology companies and ecosystems, so that we can see the full evolution we have experienced as human beings:

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 19: The “Segoe UI” font, used by Microsoft since 2004.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 20: The “Roboto” font, used by Google since 2011.

Aa Bb Cc Dd Ee Ff Gg Hh Ii Jj
Kk Ll Mm Nn Oo Pp Qq Rr Ss Tt
Uu Vv Ww Xx Yy Zz

Figure 21: The “San Francisco” font, originally created in 2014 and integrated natively into the Apple ecosystem in 2015. Its outlines have been slightly darkened artificially because the original version is barely visible.

Reading and Writing Today

We have finally reached the present, having traced the evolution of language, reading and writing, and lettering, both handwritten and typed, throughout human history. One might think that this brings the story up to date: digital devices have their place in our lives, and typing is viewed as another valuable professional skill, just as it was in the early twentieth century.

We must not forget, however, that this conclusion was valid for only two reasons. First, during the mechanical age, handwriting remained the main means of written human communication. Second, typewriters did not permeate our activities primarily because they had limited usefulness in everyday settings.

In other words, if you wanted to communicate with someone, the most natural option was still to write a letter by hand. With the arrival of digital devices, however, this is no longer the case. Our main means of communication, including the one used to write this report, relies entirely on typing. Letters have become completely secondary, and communication through a keyboard, whether virtual or physical, has become the dominant medium for both formal and informal communication.

Today, children learn to read and write on a cell phone or tablet long before developing these skills through school instruction. This is where, for many people, our position as a center for educational innovation seems somewhat contradictory. If we advocate an innovative technological transformation of the classroom that faithfully reflects the

reality of our species, why do we not work toward replacing handwriting entirely with technological alternatives that promote typing and the digital medium?

The answer lies in our organization's name: “Center for Educational Research, Learning & Innovation.” It sets out, in order, what we consider sound scientific practice. First, we investigate the system's needs; then, we seek alternatives that improve the learning process; finally, we innovate in their implementation. This means that innovation must first respond to a need or a shortcoming in the traditional learning process demonstrated through formal scientific research.

A frequent mistake among many “research centers” that promote educational innovation has been to jump directly to the final step. Research takes time, costs large sums of money, and rarely produces direct returns that can finance an organization's activities. Selling services and collecting commissions is much more effective at generating recurring revenue. These centers have prioritized funding models that favor commercialization over scientific verification of educational effectiveness.

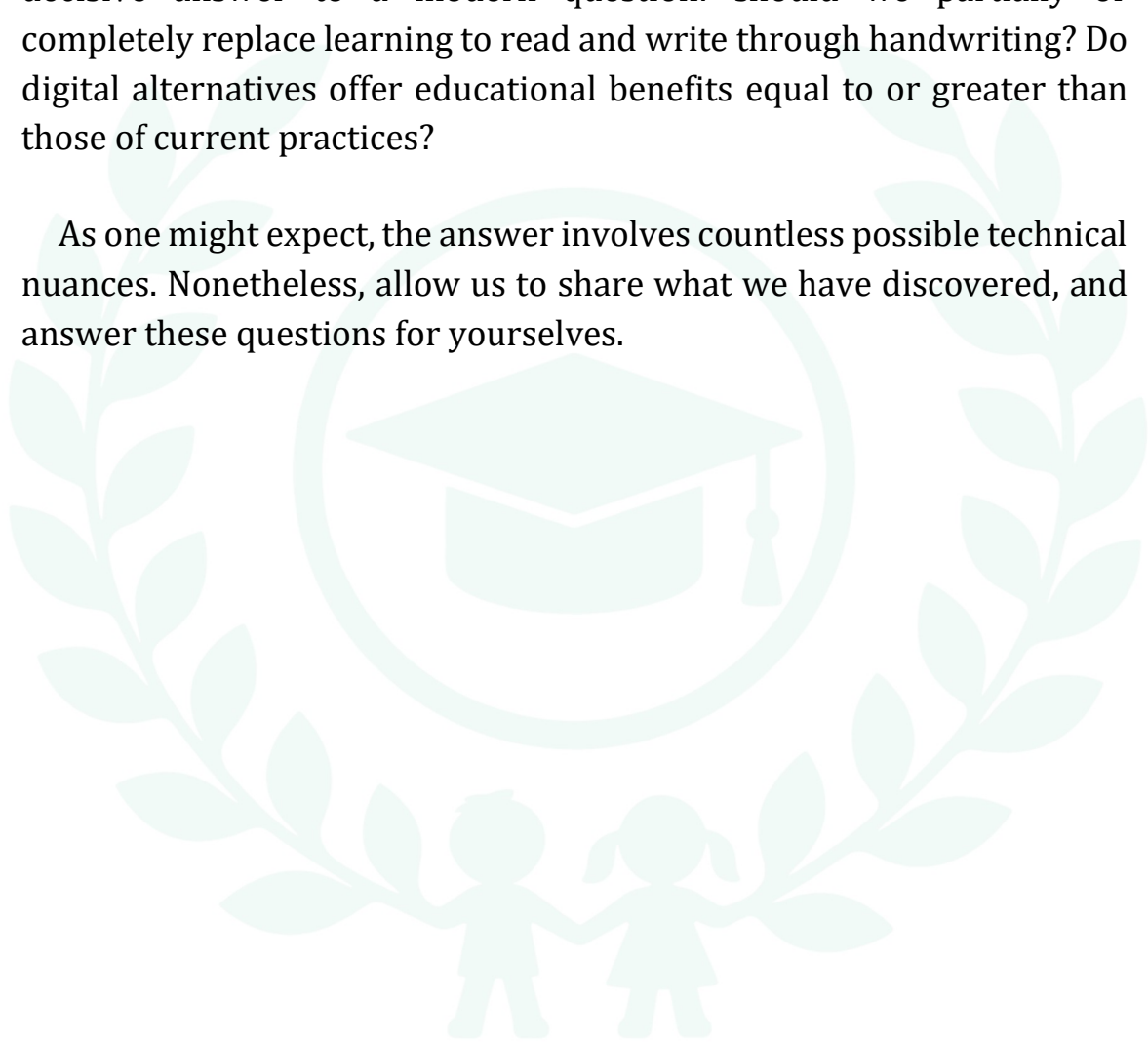
Yet the science behind these services fundamentally requires knowledge that can be obtained only through in-depth research. Because technology has been seen as the undeniable winner since its emergence, organizations have preferred to invest their money in technological innovations for the classroom, regardless of whether those investments are backed by actual science. In other words, they do not know whether the tools they promote and sell are truly improving the learning process.

At CERLI, we have exercised old-fashioned caution and committed ourselves to research, regardless of the immediate benefit it may or may not offer us. We continually advocate new technologies that have sufficient theoretical grounding and empirical evidence to revolutionize education. Yet just as we have discovered and promoted remarkable, powerful tools, we have also encountered scams, failures, and mere

experiments, which our thorough research has enabled us to distinguish.

For this reason, and with a detailed understanding of why reading and writing are so important in the curriculum, we have decided to investigate in depth the traditional and technological methods used to teach these skills to today's children and adolescents. We seek a clear, decisive answer to a modern question: should we partially or completely replace learning to read and write through handwriting? Do digital alternatives offer educational benefits equal to or greater than those of current practices?

As one might expect, the answer involves countless possible technical nuances. Nonetheless, allow us to share what we have discovered, and answer these questions for yourselves.



Which Should We Choose?

To establish a framework for a fair discussion, we must understand why reading and writing are taught in the first place. As we saw in our historical analysis, in the earliest period of human history, education served as an instrument of functional training reserved exclusively for aristocratic elites. Reading and writing fulfilled a role directed solely toward a specific task, such as managing accounting information, preserving ancient writings, or working as a scribe.

As classrooms opened to the general public, however, these purposes changed significantly. Preparing for a professional career remained an extremely important part of education, but it was no longer the system's sole focus. Access to knowledge took on a humanistic purpose: the aim was for people to know more about the world they lived in while preparing to become recognized, productive members of society.

In this sense, reading and writing were more a consequence of this globalization of knowledge: how could someone learn without being able to read manuals or write down ideas? Analyzing, understanding, and producing texts, along with handwriting, all have a dimension of social inclusion in which the aim is full participation as citizens. We cannot participate in a world seeking to become global if we cannot communicate beyond the spoken word.

But the world continued to advance, and the development of educational psychology gave the educational community a new approach to reading and writing. From an educational perspective, it is a process that brings together cognitive, motor, emotional, and social

functions. Students do more than learn to read books and form letters: they also develop their ability to think, organize ideas, analyze in depth, and pay attention to detail. The central issue is no longer whether a child can read and write, but how the child does so. This approach itself provides valuable information about children's development that is essential for educational innovation.

As a result, handwriting ceased to be valued merely for its aesthetic or formal qualities and became a practical exercise involving multiple key aspects of children's overall development, including visual-motor coordination, speed of thought, depth of analysis, kinesthetic memory, and attention span. This is the education system's current curricular framework, in which learning to read and write, at least in the early grades, has a dimension extending beyond the simple ability to produce and understand a text.

Digital typefaces, by contrast, with their technical simplicity and hand-keyboard coordination, were designed to make reading and writing quick, easy, and accessible to anyone. They were never intended to foster the same aspects of child development, and however supportive of technology modern society may be, we cannot simply assume that they can do so as well as or better than traditional writing.

Something similar occurs with reading in a digital medium. Its typefaces, the density of information displayed on screen, and the lighting technology used to show that content were all designed for practicality, adaptability to users' preferences, and access to thousands of documents and books without having to carry them physically. This does not, however, mean that the technology was designed for our brains to process information in the same way as in a physical medium.

In both cases, then, we find ourselves in the same position: it is not self-evident whether both approaches are equally valid or whether one is superior. Such a claim requires much deeper research comparing how these two ways of reading and writing operate psychologically, with an emphasis on children's cognitive development. To do this, we will

separate reading and writing into their two components and compare the areas in which each approach has an effect.



Reading

Beginning with reading, there is an almost universal consensus that, at least from the perspective of letter recognition, analysis, reading comprehension, and retaining content, text read on paper has an advantage over text read digitally. This does not necessarily require the text to have been handwritten; it simply establishes fundamental differences favoring reading on paper over reading it on a screen.

Studies such as *“Reading Linear Texts on Paper Versus Computer Screen,”* conducted in 2013 by Anne Mangen, Bente Walgermo, and Kølbjørn Brønnick, have shown tangible advantages of reading on paper over the digital option. A randomized controlled experiment involved two groups of Norwegian students between 15 and 16 years old from two secondary schools. Over one hour, each group was presented with different texts of between 1,400 and 1,600 words, with occasional images, selected from the PISA Reading Centre's test bank. One group read the texts in print, while the other read them as PDFs on a computer screen.

A subsequent computer-based test using multiple-choice and short open-ended questions sought to identify an effect on reading comprehension associated with the format in which the information had been presented ¹². The results were then statistically adjusted for variables such as sex, vocabulary, and each student's individual reading ability.

If you are wondering how this was possible, diagnostic tests were administered before reading to measure these differences reliably.

¹² Students were allowed to reread the texts while answering. The only difference was that those using PDFs had to switch windows to view either the questions or the document.

Vocabulary was assessed with a conventional semantic vocabulary test, which primarily measures whether students recognize a word's correct meaning. Students were presented with 24 questions in which they had to choose the correct synonym from three options.

Each student's individual reading skills were also documented using specialized software that presents strings of semantically unrelated words. In this test, students have four minutes to complete as many word strings as possible by inserting spaces at the boundaries of each word. For example, if the string is “penciltablebluecar,” students must separate it into four individual words, producing “pencil table blue car.”

The initial finding was that, although the groups did not differ significantly on the diagnostic tests, meaning that their individual reading comprehension and vocabulary levels were similar, those who read the documents digitally performed significantly worse than those who read on paper, regardless of text type. Digital readers also displayed some unfounded confidence in their actual comprehension, suggesting that reading in this format involves more superficial information processing ¹³.

The actual reason for this advantage is, however, open to debate. To begin with, we must recognize that the different characteristics of the two formats will encourage different strategies for processing the text. Sustaining attention on an inert, unchanging sheet of paper, for example, is not the same as doing so on a screen with hundreds of visual stimuli, push notifications, and the need to scroll manually through the material.

In that study, for example, the most noticeable differences in attention and reading comprehension arose mainly because students with paper documents did not need to focus on scrolling to continue reading or switching tabs between the material and the application containing the questions. Other variables include eyestrain caused by screen brightness and display technology. This indicates that, at least from this

¹³ This is evident from the same study's finding that actual reading time did not vary significantly between groups. In other words, even with similar reading times and similar prior abilities, the differences remained.

study's perspective, the differences can be explained by format-related problems and could be reduced with certain forms of support in the digital version.

Although this can be understood as an argument for reading on paper, it does not encompass every possible digital configuration. Because the digital medium is more adaptable, we need stronger grounds to claim that all reading in a physical format is superior in reading comprehension to all digital reading.

We therefore turn to our second reference: the meta-analysis *“Don't throw away your printed books: A meta-analysis on the effects of reading media on reading comprehension,”* published in 2018 by Pablo Delgado, Cristina Vargas, Rakefet Ackerman, and Ladislao Salmerón. It brings together and analyzes the results of 54 other studies from 2000 to 2017 directly related to the effects of digital reading, with more than 170,000 participants in total. The study aimed to estimate the actual effect of each approach on reading comprehension and identify possible moderating factors that might influence the results.

In every case, reading comprehension was compared using identical texts read on paper and on different digital devices. Only linear texts, meaning texts that did not require students to navigate the web to read them, were included. They represented different literary genres, were written in the participants' usual language, and were read by participants with no history of learning difficulties. Reading was also silent and individual, with different time frames: some studies allowed unlimited reading time, while others imposed predetermined limits.

To evaluate these results, 16 variables that might influence them were coded, and statistical regressions were then used to assess their actual impact on the overall findings. These variables were educational level, text length, time frame, device type, literary genre, the need to scroll, whether readers could consult the text while answering questions, the type of reading comprehension assessed (textual, inferential, or mixed), strategy requirements (whether readers could read freely or were required to use specified study strategies), the studies' publication

status, publication year, sample size, assignment to conditions (whether participants were distributed across groups or each person read both formats), test type (specially designed or standardized), and the assessment medium (paper or screen).

The results were striking: on average, people understood texts significantly less well in a digital format. Although the difference was not enormous, it was educationally significant, corresponding to approximately two-thirds of the annual growth in reading comprehension at the elementary school level. That was not all: as the variables were adjusted, the gap changed dynamically according to different parameters. Let us look at some examples:

- When reading time was limited and students had to manage it under pressure, digital readers made more errors and retained less information.
- When texts were informational or expository, paper showed a very clear advantage over screens. For narrative or fictional texts, however, the differences almost disappeared.
- More recent studies show even larger gaps than older ones, meaning that the more accustomed we become to reading on screens, the more our ability to analyze a text in depth declines.

The other variables considered did not yield consistent significant variations between the approaches, indicating that their differences were not sufficient to warrant consideration in a proposal for educational change. Two of these variables, however, showed signs of interesting trends even though their variation did not reach a sufficiently high level of statistical significance.

For example, comparing the devices on which students read showed that print had a more pronounced advantage when digital reading took place on a computer than when tablets or cell phones were used. This may be because large screens, with greater dispersion of content and

more distractions, make it harder for the brain to remain attentive to detail for extended periods, encouraging more superficial reading.

The other variable that showed a notable difference, though not a sufficiently strong one statistically, was scrolling. For anyone unfamiliar with the term, this is the action users take to move digital text downward so they can continue reading. When readers had to do this repeatedly, paper had a much greater advantage; that advantage declined considerably when students read fixed pages or in full-screen mode. This can be explained by the way scrolling interrupts visual continuity, making it harder for our brains to retain information.

All of this, together with other studies we have chosen not to discuss but considered in our analysis, leads us to a clear conclusion. Paper remains more reliable and effective for reading comprehension and reading development, especially in the early grades. The disadvantage can nevertheless be reduced when students are taught digital reading strategies and the software is appropriately adapted so that its basic design does not hinder reading.

Reading digitally does not necessarily make us worse readers, but it does change how we read. In education, especially when we are first learning to read, paper may be more effective at developing reading comprehension and concentration, while digital reading encourages speed and multitasking at the expense of those two abilities.

We will discuss the implications for the classroom later, but let us clarify that, although the preceding statement may sound like an endorsement of reading on paper, speed and multitasking are hardly irrelevant in modern society. It does show, however, that this educational trade-off would come at a cost and would have serious consequences if traditional methods were abandoned entirely.

Writing

While paper won decisively in reading, writing is an entirely different world. Unlike in our previous example, writing skills are not so easy to standardize and measure. What does “writing better” mean in terms of format? Does it mean being able to produce longer texts? Offering readers a better experience, greater readability, and better comprehension? Conveying ideas fully and consistently? Learning to reproduce and distinguish letters and words? Doing all the above effectively, regardless of our individual characteristics?

Answering the original question is far from straightforward, and many research groups have made substantial efforts to explore it. Even so, there is arguably insufficient empirical evidence to support a widely accepted answer. We have therefore decided that the best way to address this dilemma is to answer each of the preceding questions individually, considering which format allows each goal to be achieved more effectively in statistical terms.

Beginning with the first question, typing clearly makes it possible to produce longer texts while reducing the time and cognitive effort involved in composing them. Motor fatigue is considerably reduced when we use a keyboard, increasing both the potential length of a text and the speed at which we can produce it without becoming mentally exhausted. This is evident in studies such as *“The effect of computers on student writing: A meta-analysis of studies from 1992 to 2002”* and *“Does typing or handwriting exam responses make any difference? Evidence from the literature,”* which show that our cognitive and motor abilities are less affected when we produce longer texts by typing than when we attempt to achieve the same result by hand.

Next is the ability to offer readers a better experience, greater readability, and better comprehension. Here, the results are less clear-cut, but articles such as *“Handwriting in early childhood education: Current research and future implications,”* published in 2014 by Laura Dinehart, allow us to approach an answer. In the section *“The Development of Handwriting,”* Dinehart defines legibility and handwriting fluency as the essential parameters of handwriting quality, drawing on earlier studies that explain up to 53% of the variance in handwriting quality using these parameters alone.

In typing, speed and accuracy are fundamental skills. The ability to type many words per minute without looking at the keyboard at all is highly valued. This makes it clear that fluency, as with handwriting, is an extremely important variable in digital writing. The meta-analysis *“The roles of handwriting and keyboarding in writing,”* together with the study *“Keyboarding versus handwriting speed of higher education students with and without learning disabilities: Does touch-typing assist in narrowing the gap?”* allows us to draw some very interesting conclusions:

- Without prior training, people generally write faster by hand than by typing. Once typing became automatic, however, participants were able to match and even exceed their handwriting speed.
- Both forms of writing depend on shared motor and linguistic processes, as demonstrated by the fact that those who were initially faster at handwriting also tended to improve their typing speed most quickly.
- Although a relationship between fluency and text quality, including the occurrence of grammatical or syntactic errors, has been demonstrated, no significant improvements in the quality of typed text were found until the motor process became automatic. In other words, in both media, faster writing is associated with fewer errors, but in typing this depends heavily on the ability to make accurate keystrokes automatic.

The report *“Reading Letters: designing for legibility,”* published in 2011 by Sofie Beier, offers an in-depth analysis of the characteristics a digital typeface must have to be considered truly useful and legible. Based on Beier's research and the parameters used, we can conclude that inclusion is fundamental to digital typeface design ¹⁴. A useful typeface is one whose characters are easy to distinguish and whose text is easy to read with as little cognitive effort as possible.

We might therefore call this “essentially a tie”: both forms of writing place significant value on the same parameters. It is true that this point might favor digital writing, since, if we focus on fluency and legibility, the design and use of typefaces for typed text have much greater reach than handwriting. Nevertheless, the third point, which is unquestionably connected to readers' comprehension and experience, tips the balance back in favor of handwriting.

The same study by Laura Dinehart, along with others such as *“The effects of handwriting experience on functional brain development in pre-literate children”* and the thesis *“Efecto del tipo de escritura y la longitud en el reconocimiento de palabras nuevas,”* explains that human beings respond favorably to handwritten text and that the activation of reading circuitry during handwriting strengthens perceptual and semantic integration. This means that handwriting connects us more deeply and emotionally with what we write, making our texts more consistent and coherent conceptually.

All of this is also directly connected to our next point: which of the two media improves the process of learning to reproduce and distinguish letters and words? Here, an advantage for handwriting emerges again, since the thesis mentioned above explicitly describes how neurological evidence supports a handwriting advantage in graphemic and phonological learning.

This is reinforced by the study *“Handwriting or Typewriting? The Influence of Pen- or Keyboard-Based Writing Training on Reading and*

¹⁴ Guidelines such as the Web Content Accessibility Guidelines evaluate typefaces and interfaces for readability, taking into account contrast, shapes, and users' potential reading difficulties.

Writing Performance in Preschool Children.” Its researchers show that, in their controlled experiments, the group trained through handwriting performed better in word writing and showed a tendency toward better word reading. They explain this on the basis that handwriting enhances letter memory through sensorimotor traces, something that cannot be achieved with a keyboard.

Finally, and no less importantly, we must consider which of the two options offers all of the above while minimizing individual variables. In other words, which would yield better overall results for a group with diverse motor skills and learning difficulties? Here, technology's considerable adaptability makes a powerful case, since it is less dependent on motor factors and its operation can be adjusted to potential differences in each individual's development.

It would nevertheless be naive to assume that handwriting lessons cannot be adapted to account for possible motor difficulties and even help reduce them considerably. Although typing is cognitively and physically simpler, this does not mean that it is actively helping to reduce potential challenges.

The analysis *“The Neuroscience Behind Writing: Handwriting vs. Typing—Who Wins the Battle?”* together with the recent study *“The impact of handwriting and typing practice in children’s letter and word learning: Implications for literacy development,”* explicitly shows that, although typing helps reduce the influence of individual factors during writing, it does not address the possible causes of these difficulties. This is why handwriting, when used in specialized treatments or interventions, offers greater educational value, at least in developmental terms.

In other words, typing does not help improve students' abilities or overcome the psychomotor obstacles they face, but it does eliminate their influence on writing. Although it allows texts to be created without significant individual factors coming into play, it forgoes all the advantages identified in the questions answered earlier, where handwriting ultimately prevailed.

In conclusion, handwriting is much more effective at building a genuine emotional and educational connection with a text, but typing is an essential skill in the modern world and deserves our full attention. By understanding their differences, we can create learning activities that use both, allowing them to reinforce each other and avoid any unwanted effects on students' writing abilities.



Combined Instructional Strategies

Having answered which medium is superior in each category, we would like to consider one final perspective as we bring this report toward its conclusion. Does learning to write with a keyboard create additional difficulties in learning to write on paper, and vice versa? Does the fact that digital reading is less useful for reading comprehension than reading on paper mean that screens must be avoided in the classroom at all costs? Ultimately, the answer to these questions is no.

Learning to write through one particular approach does not eliminate the possibility of learning and refining the other. Although evidence shows better development when handwriting is taught first and digital writing follows, this does not rule out including both in the education system in their respective forms. As we saw in the conclusions under the second point of the previous section, the two media draw on similar sets of motor and linguistic processes and therefore share a foundation of transcription skills. This means that learning one inherently makes it easier to master the other.

We should recall that the education system had difficulty accepting that neither print nor cursive handwriting was significantly inferior to the other. Even the most recent studies of reading and writing in education show that it is possible to begin with print handwriting and then introduce cursive as a complement. Nor can we ignore that, although print is easier to learn and write than cursive, it does have certain limitations, including difficulty writing quickly, maintaining uniform letter size and spacing, and avoiding confusion caused by the mirror-image relationship between certain letters.

This discussion gives rise to combined instructional strategies, understood as adaptations and variations in the standard process of teaching reading and writing. These strategies seek to address the difficulties our students may face, including motor difficulties, learning difficulties, or even simple individual preferences. Here, teachers take on a mediating role, helping students recognize when and how each strategy may offer greater advantages.

For handwriting, for example, centers specializing in psychology and early handwriting development advocate a new handwriting variant known as “simplified cursive handwriting.” This is a kind of hybrid that preserves the structure and connections of cursive while using rounder, more uniform letterforms to make writing easier for children. The pronounced differences between uppercase and lowercase letters become more a matter of size on the page, while stroke speed is maintained through the links between letters.

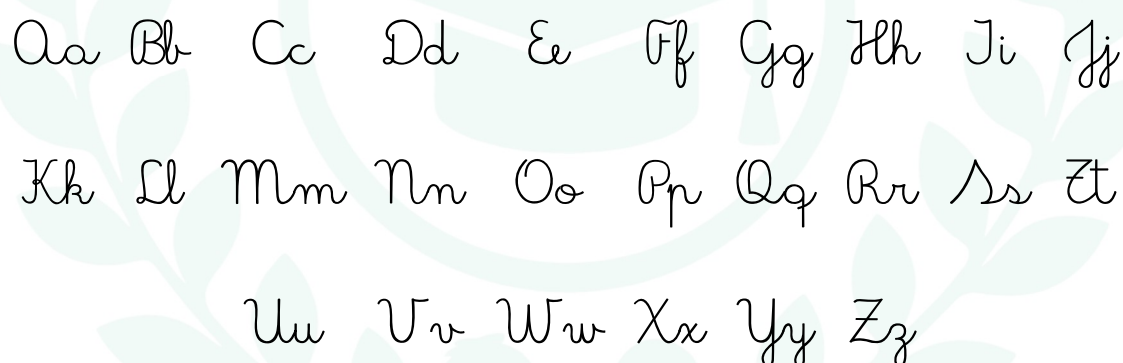


Figure 22: An example of simplified cursive handwriting. Version 2.3 of the ParaProfesores font.

Once students have acquired this handwriting foundation, they can refine it and progress toward more formal styles of cursive or print handwriting that are fluent, regular, and legible. From this point, it would be entirely feasible to explore educational approaches that also integrate typing as a natural extension of writing proficiency.

Something similar happens with reading: combining media, strategies, and instructional pacing is the key to comprehensive literacy, allowing the format to be adapted both to contextual demands and to

individuals' natural abilities. Today, reading is not limited to printed material; it also includes interacting with screens, links, images, hyperlinks, and digital environments that expand the boundaries of traditional text.

This reality presents education with a challenge: how to connect reading on paper with digital reading without falling into simplistic dichotomies between “traditional” and “modern.” CERLI's conclusion is that, far from being opposed, these two ways of reading can and should complement each other. Reading on paper supports concentration, deep comprehension, and long-term memory because it offers a less fragmented environment more conducive to cognitive immersion. Digital reading, in turn, enhances interactivity, the speed of information searches, and the integration of different forms of expression.

The issue, then, is not choosing one medium over the other; we must teach students to move between them consciously and independently. For example, a text read in print can be complemented by digital exploration that expands its historical or cultural context; online reading can be accompanied by underlining, annotation, or rewriting by hand to support retention; and digital tools can be used to visualize narrative or argumentative structures that previously seemed abstract.

These approaches require teachers to act more as mediators than as transmitters of information. Educators become guides who help students navigate between media, teaching them to distinguish reliable sources, organize information, and sustain attention in environments where distraction is a constant threat. The goal remains to develop flexible, critical readers who can adapt to new flows of information without losing depth or meaning.

In the words of our own research team, “Technology is a means, not an end.” Thus, a debate initially reduced to a “format war” develops into an answer broadly compatible with modern educational goals, indicating that combined instructional strategies are the right path. Now more than ever, teaching reading and writing means teaching students to think, with everything that entails.

How Can We Integrate Digital Reading and Writing?

Having established that the ideal approach to teaching modern reading and writing is a structured, planned combination of both media, all that remains is to explain precisely how to use combined instructional strategies. Compared with everything discussed so far, this may be the simplest point in the entire report, primarily because there is no single way to unite these two forms of reading and writing: it depends entirely on the teacher's creativity.

As we saw earlier, teaching simplified cursive handwriting provides a better route toward traditional handwriting models. Once we know how to write by hand, typing is introduced as an efficient, complementary way to consolidate the skills already acquired. The instructional goal then centers on understanding the text as a product of communication.

To bring typing into the classroom, however, digital strategies must be integrated within traditional ones. In the first years of reading and writing instruction, the best approach, considering the available research, is to begin with traditional reading and writing. Children can quickly develop the fine motor coordination and phonological awareness needed for a full understanding of written language. Once they have achieved basic proficiency in handwriting and spelling ¹⁵, however, we can begin introducing typing.

¹⁵ This level is generally reached at some point during the first two or three years of elementary education, by which time children today commonly have some experience with electronic devices and/or physical keyboards.

We should gradually digitize texts so that, while correcting and refining handwriting skills, we can also move into new educational dimensions, including editing, collaborative revision, and the thoughtful use of different technological tools. One effective instructional practice for this purpose is to begin with a handwritten composition, a draft, and then transcribe it digitally.

In addition to improving our typing skills, of course, this sequence helps our minds adapt to sudden shifts between analog and digital. It is also particularly useful for vocabulary development, since typing software designed for educational use includes powerful spelling, semantic, and syntactic analysis tools that can identify potential errors or areas for improvement in the original composition.

In other words, digital tools help reduce the constant need for teacher correction. This does not eliminate teachers' ability to assess progress, since most programs allow both the original text and subsequent improvements to be saved. Teachers could compile the most frequent errors and address them through a class discussion.

Since many may consider writing by hand and then transcribing digitally to be an overly vague task with little instructional value, we have designed a series of classroom exercises based on this idea. They can be modified or reinvented to assess entirely different variables or serve as a guide for teachers to identify areas requiring attention.

Each of these tasks begins with the same instruction: every student must write a short text, no more than 150 words, on a topic proposed by the teacher. The entire group must use a specified handwriting style; it would be useful to choose the style they are seeking to improve. Each student must then transcribe their own text into a predetermined digital program without automated spelling assistance. One of the following tasks is then carried out from this starting point.

Task A

Once all texts have been handwritten and digitized, the teacher distributes the handwritten pages among the students, ensuring that no one receives their own. Each student must digitally transcribe the texts they receive, at least two or three different ones, attempting to understand their classmates' wording and handwriting.

After each transcription, the program provides a transcription accuracy percentage, and the student rates the text according to the difficulties encountered, such as handwriting style, clarity, and spelling errors, using an agreed-upon scale. The texts that cause the greatest difficulty are reviewed by the teacher, who leads a group reflection on the most frequent spelling and legibility problems.

Task B

After transcription, each student is assigned a classmate's digital text. Spell-checking software will have modified this text to retain some existing errors and introduce new ones. The student must manually identify and correct as many errors as possible without automated spelling assistance.

At the end, the program shows how many errors remain uncorrected, providing an opportunity for self-assessment and analysis of revision strategies.

Task C

Software analyzes each student's digital text, identifying but not displaying the spelling errors. Students must reread and correct their own text, trying to locate as many errors as possible. Once the process is complete, the program reveals how many errors went unnoticed.

Finally, each student can conduct an individual self-assessment using questions such as: What kinds of errors do I make most often? Which

strategies helped me detect them? What differences do I notice between writing by hand and writing digitally?

Task D

After digitization, students must correct their text using guided, rather than automatic, spelling assistance. Once the correction is complete, the system assigns each student a randomly selected classmate's text. Artificial intelligence software then generates a series of reading comprehension questions based on that text, which the student must answer, supporting each response with specific passages from the text.

The goal of this task is to strengthen attention and deep comprehension in digital reading, counteracting the natural tendency toward “quick scanning” that reduces retention and critical analysis of content.

Initiatives of this kind, which may be easier or harder to carry out depending on the size of the student group, are extremely effective at quickly improving handwriting, spelling, and reading comprehension while introducing digital skills and limiting their negative effects on the preceding abilities. They integrate technology into the classroom while preserving the areas in which traditional tools remain extremely useful.

Best of all, just as we were able to conceive and design these tasks, any teacher who understands how the available technologies work can use their own creativity and judgment to design different, innovative tasks addressing other areas of the curriculum. As we stated earlier, this means understanding technology as a means, not an end.

Let us turn, however, to costs. Implementing specialized reading and writing software does not necessarily require new programs. For example, if your institution already uses LMS platforms with AI, customized institutional plans often include adapting the program to the curriculum. This means that specific AI tools can be requested for

different curricular areas, with minimal increases in the cost per student.

Of course, conventional generative AI can also be used through ChatGPT EDU plans or by creating a custom GPT model to perform these operations. Our team tested the latter option and observed the limitations of this solution. Tasks A, B, and D become impossible to carry out because they involve interacting with other students' texts. Those problematic components can nevertheless be replaced, allowing a standalone GPT to perform the tasks, albeit with limitations.

Because no proven alternatives are yet available on the market that allow customized reading and writing tasks to be integrated with AI, our conservative recommendation is to contact the institution's current LMS provider directly or engage one that natively integrates AI tools into its model, such as Toddle or MagicSchool.

Our research team closely follows advances in new tools with promising curricular proposals whose business models are still at a very early stage. This limits our ability to analyze their full potential, so CERLI will continue monitoring their progress before recommending classroom use. We will nevertheless stay informed so that we can begin recommending them as soon as they reach certain “milestones” and standards of technological quality.

Ultimately, curricular transformation is a collaborative process. The more institutions and organizations are interested in integrating digital reading and writing into educational planning, the more companies will emerge to supply the market. With more options, more and better tasks and tools will emerge, meeting all the needs of educational institutions at attractive prices. The market cannot take the first step in this situation; institutions and nations themselves must express their interest and demand.

Today, development times are considerably shorter than in the past, creating an opportunity to generate this demand quickly. Simply demonstrating an intention to integrate digital reading and writing into

the curriculum would be enough for leading providers to see a business opportunity they cannot afford to miss. It is time to move forward from traditional practices without forgetting where we come from, so that we can provide students with a better education.



Epilogue

During this research, CERLI encountered a reality we often share with all our collaborators. Thanks to the benefits of modern life, we have grown accustomed to technology being the only tool used for innovation. Yet we forget that education was a science long before modern technology, and that traditional techniques were also supported by extensive research and analysis.

Imagine the classroom as a large workshop. It contains many different tools: hammers, adjustable wrenches, screwdrivers, files, axes, chisels, and so on. Each was invented to solve a different problem, and its design optimizes that task. One day, a group of craftspeople creates a new tool: the saw. This invention is extremely useful because it allows wood to be cut much more precisely and quickly, with far less effort. But the saw is much more versatile: it can not only cut but also trim, open, and smooth.

The craftspeople quickly begin developing different, better types of saws to address different situations in useful and innovative ways, and society comes to believe that the saw is the ultimate tool. Yet despite its disruptive impact and versatility, the saw remains inferior to other tools for specific problems. For driving nails, the hammer is superior. For felling a tree, the ax remains superior. For removing or tightening a screw, the screwdriver remains superior. For adjusting a nut, the wrench remains superior.

The saw revolutionized the workshop, but it did not replace the other tools. What truly changed was how craftspeople planned their work, because they now had more tools with which to explore new ideas more efficiently. But there is no ultimate tool: each has a purpose, and each fulfills a role that is not easily replaced.

The same is true of technology: its versatility and adaptability to different classroom settings do not mean that it should replace every traditional educational tool. Its characteristics certainly make it an indispensable tool that we must have in the classroom, but it will not come to occupy every aspect and context of the learning process.

Reading and writing are among these fundamental pillars of cognitive development, and their traditional teaching, with corrections and improvements informed by advances in neuroscience, is a tool that cannot and should not be replaced by a digital alternative. Digital reading and typing should be considered new curricular essentials, but not the modern replacement for reading and writing.

At CERLI, where we work every day toward educational innovation and development, we will continue advancing our knowledge of techniques for learning to read and write in the early years, and we will strive to incorporate their digital alternative directly into course content. We understand the importance of this innovation, but we respect the academic value our traditional tools have already demonstrated.

We thus reaffirm our commitment to a modern education that remembers its roots: an education that combines science, practice, and humanity to prepare citizens capable of building the future with sound judgment, sensitivity, and responsibility. The future belongs to those who can bring the new and the old together in a meaningful, useful way. For it is in that union, ultimately, that the education of tomorrow truly flourishes.

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