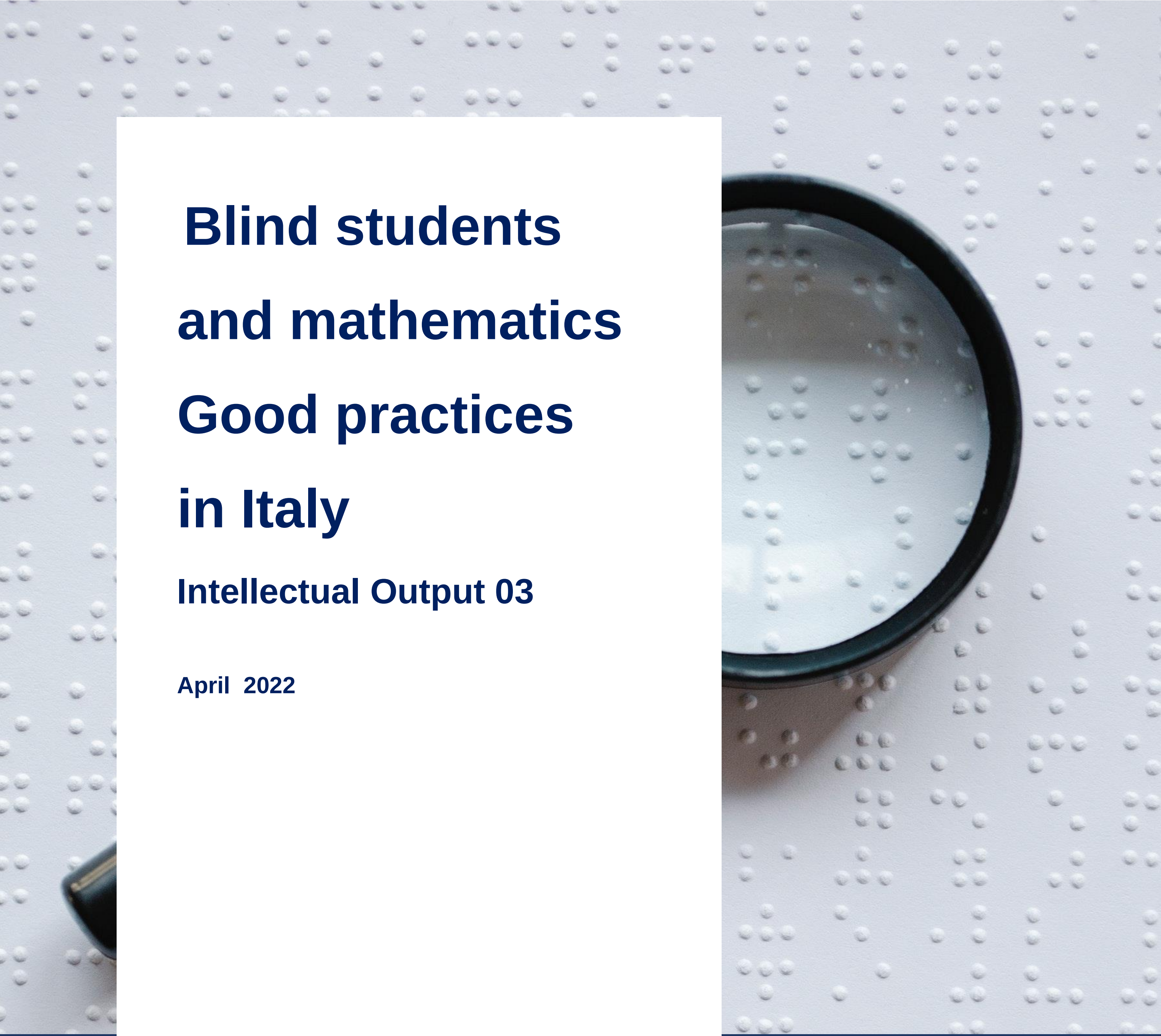

Blind students and mathematics Good practices in Italy

Intellectual Output 03

April 2022

PROGETTO DDMATH
Digital learning in mathematics for blind students
ERASMUS+ Program

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DDMATH

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DDMATH PROJECT

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Project within the ERASMUS+ program – School Education Gateway – Action KA2 - Strategic partnerships for digital education KA226 – Convention n. 2020-1-IT02-KA226-SCH-09557

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1 Introduction

Until about twenty years ago in Italy mathematics was often considered a particularly difficult discipline for the blind. The causes are many, linked in general to the limits of haptic mediation (i.e. of touch) and, often, to reduced psychomotor experiences.

For younger children, the problem of mathematical notation is probably secondary to the difficulty of developing adequate cognitive processes without the support of visual experience.

For the four operations, the primary school children use the cubarithm, a tool in which cubes are inserted on the individual faces,

Figure 1: Cubarithm (source : https://www.ciechiescuola.it)

or the dactylorhythm, today almost impossible to find since the company that produced it failed years ago.

Figure 2: dactylorhythm,(Cubarithm (source : https://www.ciechiescuola.it)

Fortunately, only in 2022 a very similar version was produced called ArithmeticBraille of the Cambratec company.

Figure 3: ArithmeticBraille (source Cambratec)

or even the dactylobraille.

Figure 4: Dactylobraille, Source Cavazza

For older students, however, as they manage to develop processing strategies that lead, in other ways, to abstraction and the consequent mathematical conceptualization, the limits of traditional Braille notation grow, together with the need for more efficient tools. Above all the computerized students, i.e. those who have acquired a good competence in the use of computers with Braille and speech devices, are the ones who most of all tend to extend the well-tested advantages of the new access tools in this field as well: - greater functionality and speed than traditional Braille tools;

- access to all documents in electronic format, not just to the few produced also in Braille; - directly accessible texts even to those unfamiliar with Braille. With regard to other subjects (history, languages, literature, philosophy ...) these are achieved and well-established goals towards which our computerized student is certainly not willing to give up. There have been huge advantages in terms of functional efficiency ("Even if in a different way, I can do what my mates do"), autonomy ("I can do many things on my own, I don't depend on others at all"), access to didactic and cultural tools ("With a few adaptations, often with no adaptations, I can consult by myself all the texts that my classmates use") and, finally, communication with teachers and classmates ("Everyone can read, immediately and without effort, what I write; the teacher can also follow my job and really be my teacher ").

This if we photograph the situation until the early 2000s; unfortunately it was not yet true for mathematics. In this context, in fact, for those years the advantages of the computer were still very uncertain. In those years there was first of all the problem of the impossibility of using the mathematical text even if it was available in electronic format. The devices for the blind, braille and speech, can only read linear texts (succession of known characters) but the mathematical document is neither textual nor linear. In fact, it uses a much wider set of symbols than in common use and also attributes meaning to their relative position and size (above, below, superscript, subscript ...).

2 The mathematical codes in use until 2006

Since the appearance of the first personal computer it has been understood that it is certainly not impossible to define a textual and linear system of mathematical writing.

Latex is an efficient and complete linear writing system, widely used in the scientific and university environment, in which the symbols and mathematical structures are indicated with short textual acronyms. Subsequently, MathML acquires more and more importance: the final two letters of the acronym (ML which stand for Markup Language, a language based on markers) denote clear links with XML and HTML and therefore with the Internet. MathML is in fact a code based on XML and approved by the W3C, the worldwide consortium that defines the rules of the web and the internet. Both Latex and MathML are based on a very complex and verbose textual source code (especially for MathML), which can be transformed into a graphical mathematical text by a visualization program. However, it is not accessible to blind people who can consult and manipulate only the source code. The use of Latex and, above all, of MathML by blind users, even if technically possible, is therefore very complex and problematic especially in the didactic context. Accessibility to Screen Readers is in fact a necessary but not sufficient condition to have an efficient and truly usable environment. But not only. At school the mathematical text must not only be read or written: mathematical expressions must be elaborated, analyzed, transformed, manipulated, demonstrated, solved ... and it is in these activities that even the Latex source code is absolutely unsuitable. In general, writing and, above all, manipulating a mathematical text using only the computer keyboard is complex for everyone, certainly much more complex than performing the same operations with pen and paper. Let's think, for example, of how many calculations or simplifications can be performed quickly on paper with a few strokes of the pen while on the computer they require a series of complex steps, especially if you want to keep track of the intermediate work (and not delete or replace permanently) to make it possible, in case of errors, to review the work carried out.

The above reasons have prompted the research centers connected to the world of accessibility to promote the development of new IT solutions.

In Italy, the first research was started by the Cavazza institute in Bologna. The Institute was once a boarding school that welcomed all blind children from the Emilia Romagna region from the age of 6 to the end of high school, in a condition of segregation. In the seventies in Italy, with the closure of all the special institutes, the Cavazza institute had to rethink what its mission should be, therefore it equipped itself with a thriving center for research, experimentation and evaluation in the field of typhlotechnics.

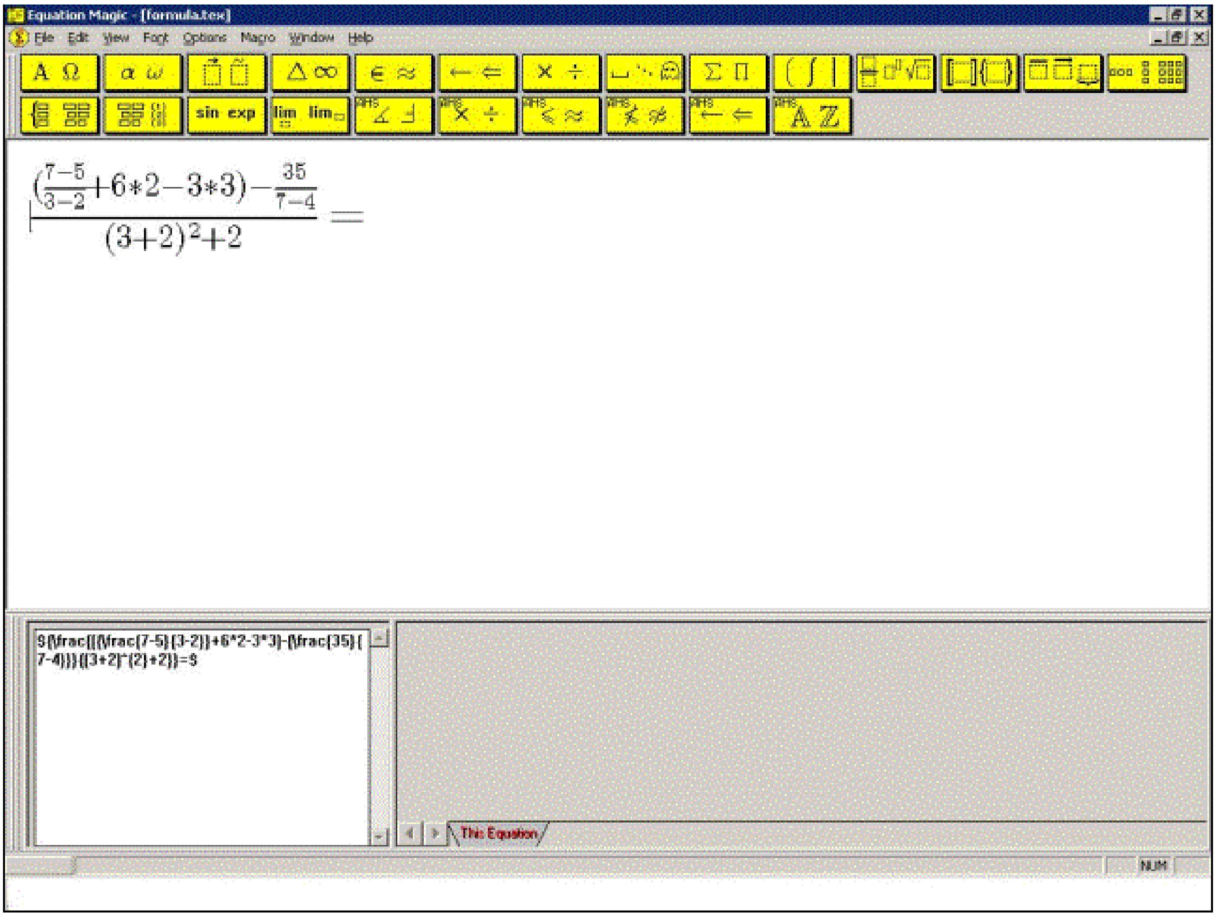

Figure 5: Braillemath (source www.Cavazza.it)

Among the solutions developed there was the Braillemath program which had a limited diffusion from 2003 to 2010, so it was subsequently abandoned. Braillemath set out to translate mathematical expressions into 6-dot Braille and into speech.

Meanwhile, starting from these considerations, the European project LAMBDA began in 2001 (with completion of work in 2005), which devised a system based on the functional integration of a linear mathematical code and an editor for viewing, writing and manipulation of the mathematical text. A new code was built (the LAMBDA code), which has a close connection with the MathM, therefore it is always possible to convert, automatically and unambiguously, the LAMBDA code into MathML and vice versa. From MathML, using one of the various already existing conversion systems, we move on to Latex and therefore with LAMBDA it is possible to access these formats that cover the vast majority of scientific documentation. The LAMBDA code is built in such a way that it can be presented to the user, through the editor, in a compact and easy-to-use way with Braille devices.

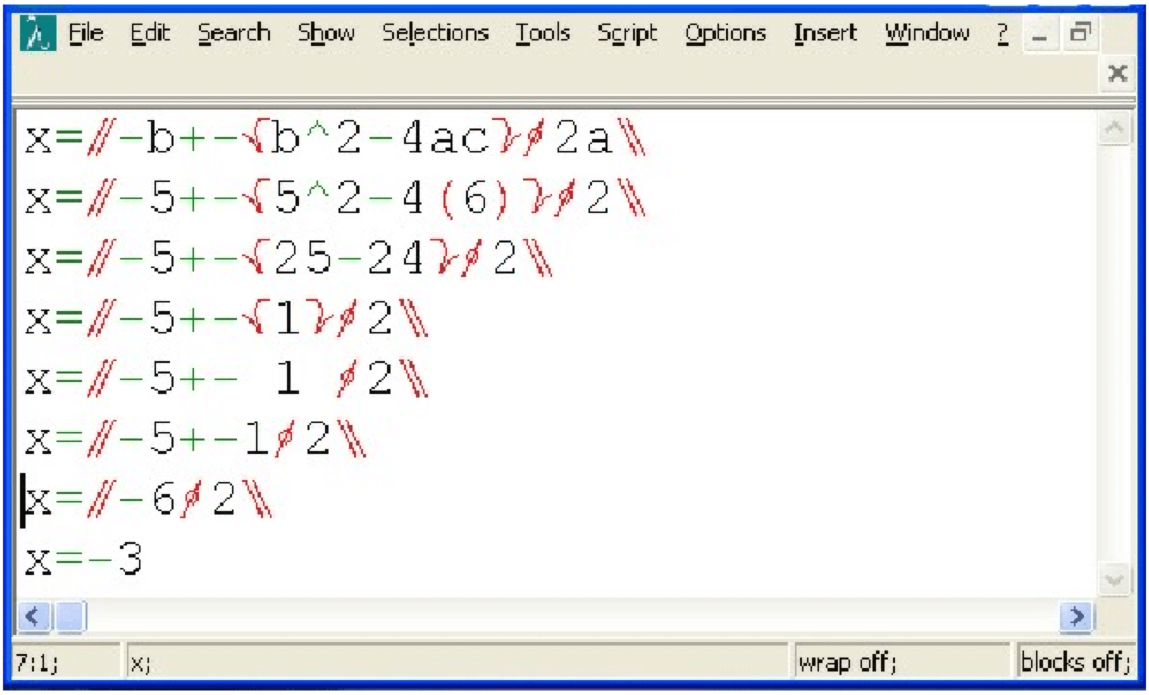

Figure 6: Lambda Editor V.1

The LAMBDA editor has a very important function. Like the Latex and MathML visualization programs, it transforms the source code so that it presents itself to the user in the simplest and most immediate way for him, that is, for our blind users, a linear code that can be easily consulted on the screen and with speech synthesis. But, another fundamental difference, the LAMBDA software is an editor, not a simple browser, therefore it allows the user to write and manipulate the formula, not just to read it as the Latex and MathML viewers do. The LAMBDA source code remains hidden from the user: he has no need to access it because he can manage it easily and completely through the editor.

The compactness of the LAMBDA code thus displayed is obtained in the first place by showing the symbols and mathematical markers with a very small number of characters, often only one; the risks of misunderstandings and the difficulties of understanding are overcome thanks to the management software that provides various alternative reading modes: the speech synthesis can pronounce the name of the element or read the entire formula in natural language, in addition the name of the element on where the cursor is positioned always appears in full on the status bar which can be consulted both with the Braille display and, again, with the vocal synthesis.

The distribution and dissemination of the LAMBDA program has taken place since 2007. LAMBDA is essentially a technical tool and does not claim to change the way of teaching mathematics to the blind, and in 15 years it has also had important repercussions on teaching, the same way the computer had in other disciplines. We believe that it is important to manage and not suffer these relapses, avoiding technicalities and always thinking from the point of view of the pupil. Lambda is currently used in Italy by 1100 students aged 10-11 (end of primary school) up to university.

In Italy, the Polin Laboratory of the Department of Mathematics of the University of Turin was born recently on the issues of access to scientific studies.

Figure 7: Weba page of Polin Laboratory

It was officially established in May 2018, as part of the scientific-technological sector of the "Research project for the identification, use, dissemination and development of new technologies to encourage active participation in university studies by young people with disabilities and SLD, from the point of view of the principles of universal accessibility, didactic personalization and inclusion ". The coordinator is prof. Anna Capietto - Professor of Mathematical Analysis and Contact for Disability in the Department of Mathematics “G. Peano "of the University of Turin - and prof. Marisa Pavone - Professor of Didactics and Special Pedagogy at the Department of Philosophy and Education Sciences and Rector's Delegate for Disability at the University of Turin.

Basically, from the narrative just carried out, it is possible to understand that theological solutions for accessing mathematics are available and used by students, but nevertheless there are still problems that could also find a solution, or at least an improvement in the future, also thanks to computer science, for example:

3 the management of graphs, for example in the study of functions.

The European project in the IST field called BlindPAD, coordinated by the Italian Institute of Technology Foundation of Genoa, worked on this theme from 2014 to 2017. Its prototype (which they hope can become a commercial product) can be consulted from the project web page:

https://www.blindpad.eu/ (2021)

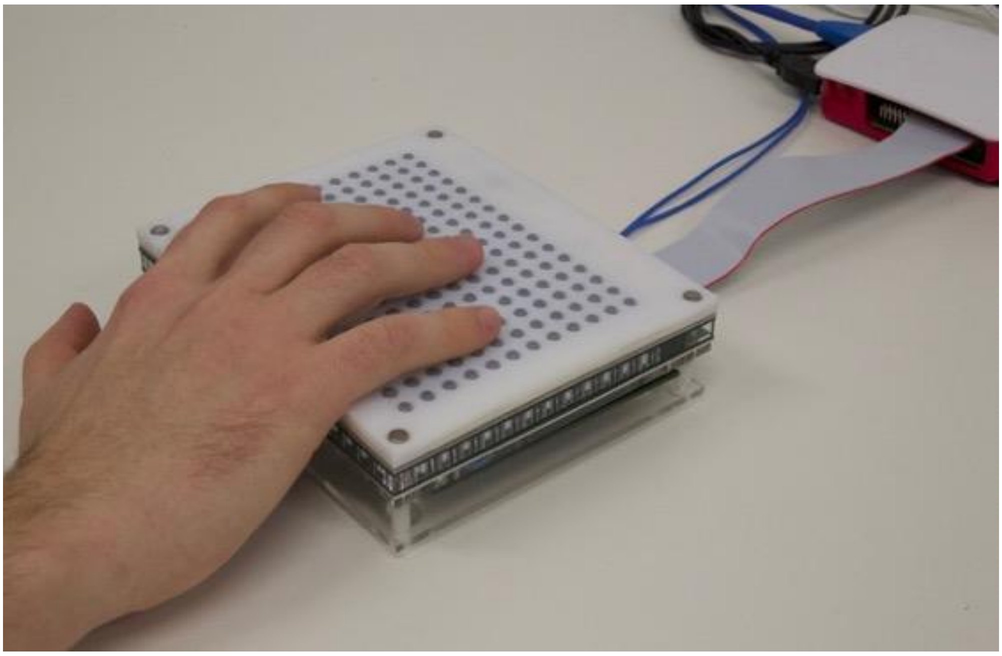

Figure 8: BlindPad (source https://www.blindpad.eu/)

BindPAD built a tactile tablet made of hundreds ‘taxels’, that are the tactile equivalent of the pixels. Images are transformed into tactile representations.

Further proposals for tactile pads are available on the market, but for the moment they remain inaccessible due to the high cost required by the type of construction technology of these instruments.

4 Low-cost production of school books on mathematics, geometry, chemistry in Lambda

In Italy there are several centres that offer transcription services of school math books in Braille, in the Lambda format. The main users of this service are the Italian provinces, the metropolitan cities that have commissioned the transcription of books for users in their territory, the schools that have enrolled blind children. Owning the math book in integrated schools means that blind students of middle and high schools have the opportunity to use the same teaching material as their peers and can therefore perform the same exercises, study on the same texts, follow the same educational path , and all this makes the meaning of the word inclusion real.

Among the most active centres that carry out the transcription of mathematics texts are the centre for the blind of Brescia, the Giuseppe Paccini association of Verona, the Italian Library for the Blind "Regina Margherita", and other centres linked to the Italian union network of the blind and visually Impaired.

The transcription of school books of mathematics, geometry, physics, chemistry in Braille, however, requires the use of an experienced operator whose work is essentially done manually, that is, with a limited possibility and exploitation of automation systems in the conversion. Therefore, the transcription cost is generally high, on average around 7-12 € per page.

Among the tools used for the automation of transcriptions is the use of the INFTY mathematical OCR, whose recognition quality of the mathematical text is very appreciable if the original copy is of good quality, preferably in PDF. However, as is well known, school texts have a general layout and graphic arrangement made up of different blocks, images, graphics, for a better approach to study and memorization.

However, this layout mode reduces the recognition potential of the OCR Infty, and extends the working time for corrections and for linearly recomposing in Braille the text recognized by the program.

It should also be noted that over the years, starting from 2004 by Law 4/2004 also known as the "Stanca Law", solutions have been active to supply also school books in digital format for pupils with disabilities. Among these:

- ✓ After a few years, a Memorandum of Understanding was signed on the use of textbooks by blind and visually impaired students, which is renewed annually (the last expires on 31 December 2021) between the Italian Publishers Association (AIE), the Italian Union of the Blind and the “Regina Margherita” Italian Library for the blind in Monza. A similar agreement is also stipulated with the Italian Dyslexia association. In this protocol "AIE undertakes to promote among the associated publishers of the Group itself attitudes of active availability towards initiatives aimed at facilitating the access of the blind and visually impaired to textbooks". This is a non-binding promotion with reference to texts in PDF format, whether they are accessible or not.

- ✓ The DIRECTIVE (EU) 2019/882 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 April 2019 on the accessibility requirements of products and services is also mentioned.
- ✓ The Treaty of Marrakech and EU Accessibility Act, which will be incorporated into Italian law starting from 2022 and will enter into force from 28 June 2025. The e-books and digital content made available on the market starting from this date must also be accessible for people with disabilities.
- ✓ The establishment of the LIA Foundation, which is a non-profit organization that promotes the culture of accessibility in the publishing field.

These are important initiatives that are having the merit of reducing the restrictions and rights of distributing texts in electronic format for disabled users.

In fact, today, thanks to this protocol signed by the Italian publishers association, the library for the blind in Monza and the Italian Dyslexia association, it is possible for families to require (through the two aforementioned associations) the texts that can be accessed by the school.

The publishing houses, however not bound by the agreement, usually offer PDF files of their texts. It is a PDF that, however, even if it were accessible, being mathematics composed of graphic elements, would not bring any benefit compared to a paper book. With the paper book, however, a recognition work is possible to be carried out with the OCR Infty system.

A different route would be if publishers could distribute the LaTex or MathML version of the textbook to transcription centres. Thanks to today's converters, Braille production would certainly be more immediate and automated.

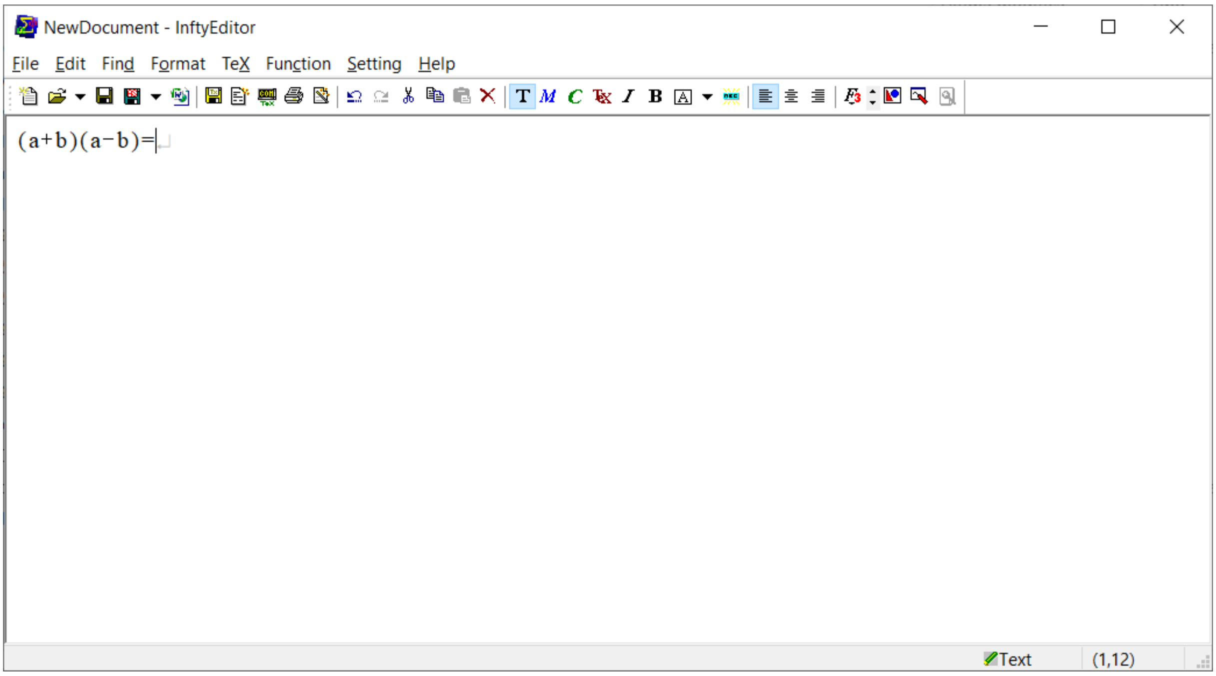

Figure 9: Infty Editor

5 Access to mathematics by the visually impaired.

Severe visually impaired students today have access to all texts through video magnifiers - whether they are optical, desktop, portable, with speech synthesis, or gradient software for personal computers - that allow to use PDF versions of school texts. However, the question for mathematics is not only in terms of reading, but also of manipulation, that is, of "doing" mathematics.

To respond to this need, the DDMATH project has developed a prototype called VISUALLAMBDA, which facilitates the insertion of mathematical text in linear format, offers spoken reading of the text, and enlarged display in classic graphic format. The aim of the project will be to experiment on the field the potential of this program, which will be distributed free of charge to teachers starting from September 2022.

Ultimately, in Italy it appears increasingly essential to start extensive collaborations between those involved in technologies for the blind and the world of schools to ensure that the potential of the new tools become determining factors for growth and development of autonomy.