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The STEM Education of Down Syndrome Children in Algorithmic and Computation Thinking for a sustainable life

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Abstract: Down syndrome is considered to be one of the most prevalent genetic causes of intellectual disability, derived from chromosomal disorder, which accounts for dysfunctions in many organs and has a characteristic phenotype, which consists of physical and behavioral features. Many studies have shown that language is one of the most impaired areas of function in Down syndrome and perhaps, the highest barrier for their substantial inclusion into formal education and community. The aim of this paper is to investigate the specific features of this linguistic phenotype, presenting the strengths and weaknesses of their language, as well as the factors that contribute to their formation, compared to normally developing children. In addition, it scopes to highlight the role of educational mobile apps, as innovative and interactive tools for the developmental learning of Down syndrome children. The results of the research indicate that their language goes through the same, with typical development sequences, but progressively erases a slowing trajectory and results in lower performance. However, with STEM education, they can develop math and digital skills, but also programming and computation thinking, in order to acquire basic skills and abilities for independent living and better vocational rehabilitation, as active members of the community.

Keywords: Down syndrome, language phenotype, factors, STEM education, computation thinking

1. Introduction

Down syndrome is the most common chromosomal disorder with a frequency of about 1/800 births and affects 25-30% of people with intellectual disabilities [1]. It is also called trisomy 21, as 95% of this population has a third copy of all or part of chromosome 21, instead of the normal two copies, while the less common types of the syndrome are translocated 21 and mosaicism [2]

The mental retardation of the syndrome ranges from mild to severe, with an observed impairment of cognitive functions, along with increasing chronological age. At the same time, the pathogenic function of the genes of the extra chromosome 21 contributes to the formation of a specific phenotype of characteristics, related to health problems, cognitive and language deficits, neuromotor dysfunction and early aging [3].

With regard to language impairment, they show a number of selective deficits in expressive vocabulary, syntax, and speech comprehension and production skills, in relation to typical developmental children [4]. However, there is considerable individual variation, as each area of their language system is affected to a different degree, while their expressive language has greater deficits than the language of comprehension [5], which is influenced by chronological age, non-verbal cognitive ability and the state of hearing.

Thus, Down syndrome children, due to their neurological dysfunction, have significant deficits that extend from their language skills to the performance of practical activities of daily life [6]. For this reason, they need personalized teaching strategies that respond to their learning style, with continuous support and innovative educational tools that will contribute to the entire development of their intellectual potential. In addition, due to their reduced attention span, they need attractive educational tools that can increase, to a higher degree, their incentives, active involvement and commitment in the learning process, compared to traditional teaching methodology [7].

On the other hand, nowadays, according to the European Digital Agenda, programming and computational thinking are considered the most modern form of literacy, which potentiates the skills of analytical thinking, teamwork and problem solving and arguably, they should be included in the

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educational activities of the curriculum courses. In the same vein, the integration of robotics in the educational process improves cognitive flexibility, promotes learning and creativity [8]. Educational Robotics (ER) is used in the teaching and learning process to promote higher cognitive functions of reasoning, programming, decision making and problem solving and is related to the fields of Science, Technology, Engineering and Mathematics (STEM) [9].

The present literature research aims to investigate to what extent and how the developmental language learning sequence of Down syndrome children is different from typical development and therefore, it examines the evolutionary process of the various areas of their language, compared to typically developed children, and how the particular features of the syndrome, as well as other factors, contribute to impairments in specific areas of their language system. Moreover, it examines the effectiveness of learning and practice through the integration of assistive technology in the educational processes, emphasizing the continuous interactions with their environment and the connection of the provided knowledge with familiar elements and experiences of their daily life [6, 10].

2. Clarification of concepts

2.1. Definition - Types of Down syndrome

Down syndrome was named by the British doctor Down (1828-1896), replacing the term "Mongolism", which was used to describe mental disorders, considering that the Mongols were more prone to them, compared to other ethnic groups [11]. He contributed significantly to the epidemiology of the syndrome, continuing the epidemiological studies that began in the mid-1800s, in which several doctors described the special characteristics of this group of patients with mental disability, among which the fact that they were short and prominent and they had flat nasal bridge, hypotension and a protruding tongue [12].

Down syndrome or trisomy 21 is a chromosomal disorder, characterized by mild to severe mental retardation and a range of physical and medical impairments due to the presence of an extra chromosome 21, which can be attributed to three possible causes.

In "trisomy 21" (92-95%), the egg or sperm develops with an extra chromosome, resulting from the fertilized egg obtained, having three chromosomes 21 instead of two. Separation failure, during the reduction of one of the chromosome pairs, usually occurs in women, while the frequency is higher in older ones. Thus, as the embryo develops, the extra chromosome is repeated in each new cell. In "mosaic trisomy" (2-4%), the probability of the extra chromosome results, due to the above condition, some cells having 46 and others 47 chromosomes. In "translocated trisomy" (3-4%), material from one chromosome 21 sticks or shifts to another chromosome, before or during conception. Therefore, the individual cells have two normal chromosomes 21, but also an additional chromosome material on the translocated chromosome [13].

2.2. Neurological profile in Down syndrome

The area of the brain of a Down syndrome child that is mainly affected is the cortex, both in neuronal density and in weaker neural synapses. Thus, as the child grows older, s/he will develop microcephaly with reduced brain volume, frontal and temporal lobes, cerebellum, myelination process and other areas of the brain with differentiated development. Particularly, the head of these infants has a larger third ventricle than normal developing infants, which is associated with the abnormal development of a wider area of the brain, such as the chamber, hypothalamus, or white substance of the brain, areas associated with cognitive processing and responsible for their cognitive deficits [3]. Moreover, they have abnormal neural interactions between the frontal and parietal lobes, which also affect the Broca area, while the abnormal development of the cerebellum creates problems of dysarthria, balance, synchronization and coordination of movements, as it is associated with executive function, reading, the sequence of learning, movement and language [13]. Also, due to the neurological development of the syndrome, from the age of about 35, they have the effects of the neuropathology of Alzheimer's disease.

3. Language development in Down syndrome

3.1. The pattern of the language deficit

What constitutes the language phenotype of Down syndrome children is a series of selective deficits, from the early stages of their development, to expressive vocabulary, syntax, speech comprehension and speech production, compared to typically developing children, of similar developmental age [4]. However, vocabulary development, as opposed to syntax, is clearly superior to Down syndrome children, as when they are called upon to recognize, identify or produce vocabulary, they perform at almost the same level as children of similar mental age, with or without mental disability. Furthermore, the delay in grammar in relation to vocabulary, which is larger in them than in other populations with intellectual disabilities, increases in parallel with the chronological and mental age and remains in the production and comprehension of syntactic structures, finding that chronological age is important for the development of syntax, while mental age is important for the development of vocabulary. Finally, Down syndrome adolescents perform better in vocabulary comprehension, less in comprehension of syntax, and face difficulty in producing syntax, as reflected in their Mean Length of Utterance (MLU) [14].

3.2. Theories of the language deficit

The language delay in Down syndrome children, usually, coexists with a generalized cognitive retardation and manifests as a linguistic deficiency in expressive or even receptive language, although comprehension skills appear more advanced.

Regarding the factors that slow down their language development, the role of auditory short-term memory is important in the first place, as 60% of these people present mild to moderate hearing loss, which also affects comprehension skills [14].

Another view focuses on the neurological structures, which are subject to language and dysfunction in Down syndrome children, since they have anatomical and neurochemical abnormalities in their brain, which are attributed either to abnormal rates of glucose metabolism in their brain, in areas related to the language function at either slower motor response rates and abnormal cerebral laterality [15]. Additionally, linguistic differences appear to be related to the lack of a dominant language hemisphere, as they do not have the advantage of the right ear, unlike typically developing children, which indicates the existence of a severe disability in language area.

Another possible explanation, for the large variation between their language and cognitive level, is provided by Lenneberg’s “Critical Period” hypothesis (1967), which argued that maximum language development takes place before adolescence, while Newport (1982) added that the specific language learning skills are not available beyond the age of 7, according typical language development. Next, Fowler (1984) reported that their language development may be consistent with the general developmental course of maturation, but it will stop or differ from the typical course due to their reduced brain function [4].

An important factor is the quality of the linguistic registration of their environment, as the speech addressed to them consists of short and simple sentences with limited vocabulary, thus not allowing them to acquire the necessary language structures. This, in turn, indicates the reduced maternal expectations for their children’s language ability [16], which reproduces the telegraphic speech they receive [17].

The hypothesis that children with intellectual disabilities have reduced motivation in information processing tasks [18], compared to typically developing children of similar mental age, needs further study on the role of motivation or lack of appropriate strategies for their language development [19-20].

Finally, one position that does not receive enough support is the institutionalization of their language, as it is argued that it has a negative effect in many areas of development, including their vocabulary and fluency. However, in a number of syntactic measurements, no significant differences were found with those growing up in a family environment [4].

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3.3. Phonology

Down syndrome children have a high rate of phonological errors, similar to those of younger children with typical growth rates. However, the inconsistency of these errors is a special feature of the phonological disorder in Down syndrome. Thus, they use phonological procedures, such as simplifying patterns and systematic sound errors - such as reducing clusters and deleting final consonants - for much longer than their typical peers. Additionally, their poor intelligibility of speech affects the linguistic skill of production and, to a certain extent, it interprets the difference between the level of their receptive and expressive language [21].

3.4. Semantics and expressive language

Although, there is a significant individual variation in the degree of language dysfunction, which depends on the field of language, which is assessed and the age of Down syndrome children, the deficits in semantic processing and especially in their expressive language are greater and even in relation to their general cognitive development [22]. Thus, their expressive language, presents much greater deficits, apparent from childhood, compared to the language of comprehension and non-verbal cognitive ability [23], as evidenced by deficits in phonology and early non-verbal requests, which lead to a slower and limited expressive vocabulary [24], which even in adolescents, rarely exceeds 3-5 years of typical development [25]. In contrast, receptive language and comprehension appear more developed than expressive language, during all age stages until the onset of adolescence [26].

The appearance of the first words and utterances, consisting of two words, takes place at a similar developmental age to the control group, while their verbal vocabulary and especially the expressive one is constantly delayed over time. At the same time, they perform lower in a number of semantic activities such as receptive vocabulary, correlated vocabulary, word-image matching and verbal (expressive) vocabulary due to semantic deficits [22].

Laws (2004) [5] states that individuals, with good phonological memory, imitate and successfully reproduce the syntactic structures of adults and based on these standards have higher performance in expressive language. However, Down syndrome children have a deficit in verbal short-term memory, due to their low level of language skills and not to a specific inherent deficiency in a system of verbal short-term memory. Moreover, their difficulty in verbal versus non-verbal skills is linked to their reduced verbal versus visual-spatial memory function. Furthermore, it has been shown that, in Down syndrome adolescents, comprehension rather than cognitive function or chronological age is a predictor of speech production ability [27].

On the other hand, when evaluated in vocabulary production, using language samples from real communication situations and not from standardized measurements, they show a delay in their expressive vocabulary, in relation to their non-verbal cognitive ability. In particular, their expressive ability is measured by the MLU of their sentences, i.e., by the number of words and / or morphemes they use, in conversation or narrative samples, and this has been found to be less than typically developing children, equated to non-verbal ability [28] or similar developmental age, with other mental health problems. Thus, while Down syndrome children tend to use more complex utterances, with more words, at a similar mental age to their typical peers, the MLU of their verbal phrases increases more slowly, despite its direct relationship to chronological age, resulting in deficits in measurements of syntactic complexity, word frequency, diversity of a fixed number of utterances and word production rate, in language samples of narration and conversation [29]. However, some Down syndrome adolescents show a modest syntactic development in late adolescence, indicating that the development of expressive language, as reflected in the MLU of verbal phrases, in sample narratives - longer phrases, vocabulary diversity - continues into the years of adolescence, at a fairly high rate in the development of expressive language, contrary to the “critical period” hypothesis [30].

3.5. Vocabulary

A high percentage of Down syndrome children (80%) start talking in the 2nd year of their life and only a small percentage (10%) in the 1st year. So, some of them will say their first words, at about the same mental age with children growing at a typical pace and specifically at 8-45 months. However, quite often they do not acquire words until the 2nd year, nor the skill of combining them until the 3rd or 4th year of their age, while they inconsistently use the newly acquired vocabulary, sticking to what characterizes much younger children [31]. Therefore, they produce their first words, usually at a much older age than typically developed children [32], with an average of 21 months and then, their progress slows down, compared to the typical sequence [24]. On the other hand, the deficits of their productive vocabulary -although with significant individual variations- are due to their hearing condition (8%), chronological age (35%) and their non-verbal cognitive ability (13%) [29], while there is more variation between typical and non-typical children in the developmental sequence to acquire their first 50 words.

It is also interesting that they find it difficult to understand words that express emotions, due to their difficulty in assessing the perspective of other people in general. In typically developed children, the first words of internal situations start from the 2nd year and after the 3rd year, show a large increase. Down syndrome children will follow the same path, but due to the general deficits in their expressive language, they produce a more limited vocabulary [33]. In addition, they use, to the same extent as their typical peers, words to express physiological states and sensory perceptions and much less words that refer to their will or cognitive ability, because they are unable to understand abstract thinking.

However, in late childhood and adolescence, vocabulary comprehension is an area of potential for Down syndrome adolescents that is compatible with or higher than their nonverbal cognitive ability, unlike other areas of language, such as syntax. Thus, older Down syndrome children and adolescents show typical or accelerated vocabulary development, compared with normal developing children of appropriate developmental age due to intervention programs, which they have accepted to enrich their vocabulary or to the richest, stimuli, learning environment, due to their vocational training [14]. Additionally, they understand better high-frequency vocabulary with specific content, rather than the unusual and conceptually complex vocabulary. Therefore, they need more contact with a word to understand its meaning and benefit from their experience with familiar words, compared to younger children of typical development [2].

3.6. Syntax

In contrast to the development of their vocabulary, the development of syntax is disproportionately delayed and mainly in the production of language, in relation to their non-verbal cognitive ability. In particular, comprehension of the structure is characterized by developmental retardation in late adolescence and early adulthood, which may result mainly from a lack of articular loop exercise, which increases in parallel with the age and it is associated with impairments in their expressive language. Consequently, the gap between vocabulary comprehension and syntax skills increases with chronological age, while still being associated with mean mental age and inadequate auditory short-term memory, which impedes syntactic learning, because it does not allow them to retain memory and process large word sequences. Thus, compared to typically evolving children of developmental age, they have a more homogeneous pattern of syntactic use with shorter and simpler syntactic structures in their oral speech, as reflected in the MLU of their utterances and the omission of grammatical functional words and forms -as they lag behind in grammar morphology skills- [21] minimizing the risk of making grammatical errors through the use of new syntactic structures [28].

Particularly, a comparison of the language structure of Down syndrome children, mild to moderate retarded, with children of typical developmental stage, shows that they initially use two-word formation, in which they encode the same thematic concepts. In the next language stage, children with the syndrome use more words that indicate place and condition, while they find it difficult, similarly to the control group, to form hypothetical sentences and refer to past or future events [4]. At the same time, the beginning of the combination of the two words appears between the 1st and the 6th year, while the formation of the first sentences from the 1st-17th year of their age, producing simple noun and verb phrases and simple questions and negations, in which grammatical morphemes are omitted and in particular, the tense morphemes [21]. Therefore, syntactic deficiencies and not vocabulary place limitations on the narrative production [3]. However, as they use more complex word combinations, at the same mental age as typical developmental children, they gradually show slower growth rates, complexity and length of utterances and inconsistency even in already acquired grammars, indicating that they will never reach a complete knowledge of syntax.

In the past, their difficulty in achieving more complex morphological and syntactic development was attributed to chronological age, referring to "a critical period" defined by the onset of adolescence, with alternating language stages of "fast growth" and "plateau", when development it slowed down or stopped altogether and was limited to the simple syntax ceiling [4]. However, more recently, it has been found that older Down syndrome adolescents (16-20 years old) showed an improvement in their narrative language, compared to younger adolescents, using complex utterances, similar to those of a typical preschool child matched to MLU [24]. Furthermore, it has been found that the occurrence of delay in their syntactic development depends, in part, on the nature of the sample examined.

On the other hand, the fact that utterance length continues to develop, in some adolescents, until the age of 20, does not imply syntactic development, as longer sentences result from the improvement of all language skills, lexical, morphological and syntactic. It was also found that the MLU, in the context of narration and conversation, increases in parallel with the age and mainly in narration, after the age of 16 years. Thus, it seems that the narrative production, which is closely related to expressive language and syntax, is influenced to a lesser extent. Therefore, it seems that the developmental sequence in these children with atypical development is similar to that of children of typical development, compared to MLU, but the syntax develops more slowly than the vocabulary and this deviation widens over time. Otherwise, in terms of comprehension of syntax, the MLU and complexity of syntax continue to increase until late adolescence and early adulthood, rejecting the claim that Down syndrome adolescents have entered the stage of a plateau in syntax or remain at the ceiling of simple syntax and at the same time, making expressive syntax a fertile field of intervention [26]. However, even when they can produce complex utterances, they tend to shorten their sentences, using a lower percentage of long complex sentences, compared to the control group [30].

3.7. Pragmatics

Down syndrome children display a complex profile with strengths and weaknesses in the pragmatic aspects of language, similar to those seen in younger children with typical developmental interactions with their parents or other adults. Thus, from the pre-linguistic stage of development, they have many difficulties in trying to respond to non-verbal requests and therefore their interlocutors have to use verbal and non-verbal modes of communication [34].

Their potential includes the ability to stay focused on their subject, such as children with normal growth rates, of similar mental age and much more than younger children, matched to MLU. Additionally, they respond to requests for clarification in order to restore communication interruption. Another feature is adequate storytelling, with visual support, as they are able to retrieve more plot elements and references to the subject than normally developing children of a corresponding MLU or expressive language level. Also, by extending the content of their narratives with data from other sources and using a larger number of simpler linguistic utterances, they compensate, to some extent, for their deficits in expressive syntax.

On the other hand, some areas of pragmatics may benefit from the intervention, as they, usually, begin issues less frequently, than younger children of a similar developmental level. In addition, they find it difficult to construct utterances, in order to express their intention effectively and yet, they will not be the first to state that they did not understand the message of their interlocutor, during their communication, asking for clarifications or additional information [21]. However, these problems are not due to deficits in vocabulary or syntax, but to the very slow processing of information [35]. Finally, they show a low percentage of verbal obsession, off-topic language, stereotyped language in the conversation, due to the cognitive rigidity [19-20], and at the same time, impairments in the coherence of the conversation and the ability to use contextual information.

4. Assistive Technology for developing computation thinking of Down syndrome children

The incorporation of digital technologies in the education domain is very productive, successful, facilitates and improves the assessment, the intervention and the educational procedures via Mobiles [36-49], various ICTs applications [50-86], AI & STEM [87-97], and games [98-107]. Additionally, various strategies and techniques can be incorporated in educational approaches via IoT. The combination of ICTs with theories and models of metacognition, mindfulness, meditation and emotional intelligence cultivation [108-150] as well as with environmental factors and nutrition [151-154], accelerates and improves more over the educational practices and results, especially the gifted students with ADHD.

However, educational processes should not focus on the use of technology, but on the potential for interaction and the provision of multisensory stimuli, which allow the active learning and development of Down syndrome children, exploring the environment through their senses. The design of technological interfaces and the use of electronic devices for their training should take into account their particular physical and learning characteristics, but also their strong individual variation. Similarly, the choice of the suitable educational approach, but also of the appropriate social environments, is considered crucial, so as to provide a holistic orientation of their education, both towards their cognitive maturation and the adaptability of their behavior.

Particularly, their cognitive limitations relate to working memory dysfunction, which hinders the development of memorization strategies to consolidate and maintain new knowledge and therefore learning. Additionally, they do not understand abstract thinking, show a slow rate of processing, mainly, auditory information, a low level of motivation and difficulties in concentrating and maintaining their attention (mainly in the mechanisms of releasing their attention from the previous stimulus and directing it to the next stimulus). The difficulties in adapting their behavior concern deficits in socialization, communication, in matters of daily living -time and money management, safe movement-, their dependence on other people, the acquisition of digital skills to operate computers and other electronic devices and the manifestation of inappropriate behavior, due to poor emotional tolerance for failure [10, 155, 156]. On the other hand, as it is known, their learning is facilitated through practical situations, connected to their daily experiences. Furthermore, the acquisition of daily life skills multiplies their opportunities for achievement a higher degree of autonomy and equal access to the job market, which ensure them higher quality of life indicators [157].

The development of computational thinking, can contribute to this aim, because it is closely related to logico-mathematical thinking and is based on basic IT concepts, promoting the skills of programming, problem solving and a deeper understanding of the emotional dimensions of human behavior. For this reason, it should be included in educational literacy and mathematics activities of the curriculum, from early school age [8].

In the same vein, Educational Robotics (ER) facilitate the inclusion of Down syndrome children, in interactive cooperative learning educational programs, that include targeted playful activities in the Zone of Proximal Development, which stimulate the executive functions of reasoning and programming to solve problems. Feedback from the robot for performing a programmed action allows the child to reflect further, analyze and self-assess their performance The design and operation of ER concretizes theoretical knowledge, through the representation of the surrounding world, using objects as thought stimuli and achieving learning outcomes through action and its reflection. Thanks to the adaptability and prospects of personalizing robotic platforms and interfaces to their neurodevelopmental characteristics, it is one of the most contemporary strategies for improving the mechanism of intellectual planning and the functionality of visuospatial memory [9].

Recent research provides evidence that their first interactions with technology take place between 3-5 years of age, while their use, in the school environment, is also quite frequent. The most commonly used applications are the web, digital games and educational software (at a rate of 80%). Experts point out that an educational software program with a variety of creative and enjoyable activities, which takes into account their mental age, significantly, increases their motivation and self-esteem, while the multiple opportunities for systematic practice, observation and visualization of the educational material and tasks, on the computer screen, have a beneficial effect on increasing the plasticity of their brain [155, 158].

However, access to assistive technology and the use of computers requires a number of adaptations in order to make hardware and software accessible to Down syndrome children similarly to their peers, so as to enhance their prospects of inclusion in mainstream school.

Furthermore, the creation of an ICT-based activity for home or school education should meet certain conditions. The software should be designed to easily adapt to each child's learning profile and follow their changing needs while maintaining their interest and learning incentives. It is also pointed out that technology can be an important educational tool for children, when computer-based learning is integrated into a meaningful context, within which they work independently or with the support of the parent or teacher, who choose the most suitable software for them and discreetly monitor their progress, guiding their thinking, enhancing their understanding, supporting their learning and motivating them to solve problems, while allowing them room for experimentation and exploration, so that they experience a sense of achievement. At the same time, it is considered necessary that they are encouraged to learn to use a software, or to operate a robot, that the instructions provided to them are simple and understandable, that their every effort is immediately praised and reinforced, in order to acquire duration. Children should be seated comfortably so that they can move freely and have effortless access to the screen, keyboard, mouse or other input devices. For young Down syndrome children, software that can be accessed with one or two switches is considered more suitable, while devices with a mouse or keyboard are suitable for older ages. They can also use custom keyboards, small mice, touch screens, trackballs, joysticks, depending on their capabilities [159].Thus, the assistive technology provides innovative, engaging and interactive personalized learning tools for Down syndrome children, designed on the basis of their strengths and to compensate for their weaknesses, providing them with the necessary encouragement, stimulation and support, due to their intellectual disability, limitations in expressive language and reduced attention span [160].

Supporting their learning through ICT has the following advantages:

- Computer software and other ICT tools enhance their learning with visual stimuli, at the same time, as hearing aids by leveraging their visual advantage.
- Provides the ability of a non-verbal response with the press of a key, a click of the mouse or a touch of the screen, compensating for deficits in expressive vocabulary and unintelligibility of their speech.
- The computer environment meets their desire for a controlled and autonomous way of learning, as it allows them to practice systematically, strengthening their self-esteem and their incentives. In any case, before to interact effectively with an ICT device, they need some time to practice and learn the operation of an application. Additionally, the familiarity with using technology (apparatus, software) inhibits the manifestation of inappropriate behaviors that, sometimes, cause their frustration with their limitations.
- Repetition and practice opportunities lead to a gradual improvement, accompanied by positive feedback and reflected by sound effects, moving images and music, which, even in case of failure, takes the form of a prompt to try again.
- Most educational software is carefully designed with activities, structured in small steps and adapted to the learning readiness of each child, in order to experience positive learning experiences and success, without the stress of error, which often leads them to avoid behaviors of more challenging activities or even, to giving up the effort.
- In addition, quality educational software offers a well-structured learning environment, without complex stimuli and distractions, meeting their need for predictable and organized learning environments.
- Moreover, a software can be programmed to provide the appropriate learning stimuli to the child and adapt the presentation of a sequence of activities.
- The use of multimedia material - videos, images, sounds, animations - stimulates their interest in active learning and increases, significantly, their attention span (which, usually, ranges from 3-15 minutes).
- They offer the possibility of self-regulated learning, so that each child proceeds with the activities, according to his/her individual pace and having the necessary time to process the information, which are prerequisites for a correct answer [155, 159, 161, 162].

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Finally, it must be made clear that the main goal of Down syndrome children's contact with the assistive technology is to acquire early digital skills and to realize that their interaction with it is subject to a "cause and effect" relationship, since they control the sounds, they hear and the images, they see, through a switch, a mouse click, a keyboard key, or a touch of a screen.
This awareness will be the basis for the construction of their learning [159].

4.1. ICTs tools for acquiring math skills

According to some researchers, Down syndrome children show quantitative and qualitative differences in the way and rate of processing mainly auditory information, which hinder the mechanism of generalization and transfer of their knowledge to other contexts. Moreover, their limitations in abstract thinking make it difficult to perform, often, even the simplest mathematical calculations, while understanding and mastering the mechanism of the basic mathematical operations of addition and subtraction require a sufficient mental potential, concentration of attention and adequate functioning of the working memory [163].

Particularly, the acquisition of logical-mathematical thinking by Down syndrome children is achieved through systematic repetition, which provides the necessary time frame for their processing, bringing about considerable improvements in the dimensions of perception, understanding of the abstract concepts of counting and quantity. Such training is made possible with the support of the computer, which promotes their conceptual way of thinking, to a higher degree, compared to the traditional teaching methodology, as recent research has shown that the difficulty, they show in acquiring and maintaining numerical concepts is primarily responsible the use of inappropriate educational strategies, which do not correspond to their learning characteristics. On the contrary, the use of the computer, as a learning tool, allows the individualization and sequencing of a series of fun activities, creating an attractive and motivating learning environment, which are critical parameters for the effective training of these children [155].

A. A math software using multimedia and computer assistive technology was developed to learn basic math concepts - counting skills, quantity concepts -. The use of multimedia material, which presents abstract concepts, through dynamic structures, such as moving objects, can compensate for deficits in their abstract thinking. Activities include a. counting tasks, by matching objects and numbers one-to-one and learning the fixed sequence of numbers and b. pre-quantity tasks, in the sense that the last number of a counted sequence indicates the number of items in the sequence.

The research was carried out in Spain, with the participation of 23 Down syndrome children, without significant individual variation before the implementation of the intervention. The children showed considerable improvement in the acquisition of basic mathematical concepts and skills. They performed better on the matching tasks. However, it was found that they show more difficulty, as the number of objects placed in the counting line increases - for the reason that they are not tangible objects - because children have to have a full understanding of what has already been counted and what remains to be counted. At the end of each activity, they are given feedback on their performance, with a simultaneous visual display, on the computer, of the steady counting sequence [155].

B. "SynMax" is a computer application, developed in Malaysia and provided in Bahasa Melayu and English language, for the acquisition of basic numeracy skills - learning the concept of numbers and number sequence - and consists of three modules: a. acquiring the ability to recognize numbers b. matching and c. counting.

This software is designed to meet their individualized learning style, adapting the training process to their slower learning rates, due to their common cognitive impairment. In the design of personalized teaching, the factor of Artificial Intelligence (AI) has been integrated as well as the basic theories of learning -behaviorism, constructivism, cognitivism- providing activities that take into account their language deficits and according to their experiences of their environment. It also implements the theory of dual coding, which facilitates the coding of knowledge and contributes to the consolidation of learning by representing verbal information with visual stimuli.

In the initial stage of "getting to know the numbers 1 to 10", the user chooses activities with the numbers 1-5 or 1-10. Then, it goes to the "number recognition" module, the sequence of numbers is visualized on the computer screen and, at the same time, called verbally, so that the children are able to recognize them. This process is repeated three times. In the "matching" module, the student is asked to draw a line to connect the number shown on the board with the number given to them, thus improving their fine motor skills. In the last module of the "counting" the user is instructed to pop a given number of balloons.

The results of the research, with the use of this technological tool and the participation of children aged 1-13 years, showed that their attention span increased significantly, through interaction with the computer and the possibility of exploration to acquire knowledge. The children were actively involved and engaged in the completion of the activities, due to the gradual provision of the information and its multimedia presentation. At the same time, the guidance and feedback, in each module, from a "virtual" teacher worked very positively, but also the repetition of activities with an alternation of animations, scenarios, sound effects with familiar melodies to the children, creating a sense of comfort and familiarity for them [162].

C. "Divermates" (Diversity and Mathematics) is an educational program for learning mathematical concepts, which contribute to the acquisition of greater autonomy and social skills. Its flexible design is addressed to children with different abilities, following the seven universal principles of inclusive design. It uses an interactive board, depicting the numbers from 1-9, with three levels of difficulty, to perform the basic operations of addition and subtraction and to solve problems, with the possibility of analyzing their most common errors.

The activities ask students to place numbers and balls or cross out balls and place the correct symbol to perform the operation. Given the fine motor deficits of Down syndrome children, which make it difficult to use a mouse or keyboard, to enter or select numerical digits, the interactive whiteboard emerges as an ideal interaction tool, as it makes it easier for them to write the numbers, with great approach, in the right place or delete them when required. Thus, students can concentrate on the arithmetic operations, without being distracted by the limitations of writing and without potential mathematical errors, due to the difficulties of interacting with the computer mouse or keyboard.

In the relevant research, nine Down syndrome children, with different arithmetic skills, were studied and it was found that some of them were unable to understand the reasoning of the operation of subtraction. Furthermore, it was observed that the main measuring strategy they developed was using their fingers or balls as visual aids. Another advantage provided by the digital board is that it pointed out errors, which might, otherwise, not have been apparent, such as in the placement of the numerical digits [163].

D. A math software was designed in Peru to develop the math skills of recognizing numbers, relating them, counting, designing and the concept of quantity. It is a highly useful and interactive tool, installed on an iPad, for Down syndrome children aged 6-10 years, enabling them to select and move a set of pictures, in a frame, in order to complete the requested number, thereby acquiring counting skills. At the same time, the correct or incorrect choice is indicated audibly, encouraging them to continue the effort.

This application contributed, in a fun way, to the reinforcement of their mathematical skills - in Down syndrome children with mild intellectual disability - and provoked their exploratory curiosity to experiment with other functions of the application. In addition, the drag addition of the digits improved, significantly, their fine mobility [7].

4.2. ICTs tools for increasing digital skills

A. The sensorimotor problems of Down syndrome children make it difficult to use computers, while the intelligibility of their speech and their limited expressive vocabulary pose barriers to their communication. All these disfunctions combined with their cognitive disability, often, lead to the degradation of skills and their employment in inferior jobs. It is therefore necessary to train them in digital literacy skills, which multiply the opportunities for their better vocational rehabilitation.

Certainly, in an adequate percentage, they can use the keyboard, the mouse, the screen and the computer, but they need targeted programs to teach typing skills and to operate electronic devices, but also to familiarize them with software such as email, Word processing, PowerPoint, which are prerequisite skills for higher quality jobs, upgrading their standard of living [158].

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B. The tangible robotic platform "KIBO", in Tenerife, Spain, was developed for Down syndrome children, mental age 4-7 years, with a view to developing digital skills, in a typical general school classroom. It consists of wooden blocks, easy to use, that assemble them with their hands, according to a certain sequence, in order for the robot to execute a specific program. Its programming is achieved by scanning the wooden blocks, through an integrated scanner, as each of them contains a color-coded action or instruction.

It includes 23 activities, including knowledge of the features and operation of the robot, knowledge of numbers and basic operations, semantic awareness, speech therapy, increasing attention, boosting auditory memory and body awareness, improving the timing of emotional self-regulation and social relationships.

High levels of interest, concentration of attention, incentives, active involvement and engagement were found in children who, by directly interacting with the robot to play and observing its movements, were motivated to explore their environment and experiment, acquiring basic programming skills and computational thinking [8].

C. The "Bee-Bot" robot, in the shape and colors of a bee, was used in ER-Lab's 8-week research program, with Down syndrome children, with mild to moderate intellectual disability, preschool and school age. This particular robot provides the prospect of storing 40 instructions for programmed sequences, while children, with the buttons on its back, can control its movements, giving an order to start or even temporarily stop a cycle of sequences. Upon completion, the robot blinks its eyes and plays the sound of a melody to provide feedback to the children, by enhancing their incentives.

In the initial sessions, the children get to know the robot and its characteristics and in the following ones, they gradually become familiar with its operation and programming, achieving each time, a goal, with the guidance of an adult, which gradually decreases as they succeed. As the "Bee-Bot" moves over geometric shapes of different colors and sizes, representing a map of a city, it supports the spatial orientation and movement skills of Down syndrome children.

All the activities of the ER-Lab, which took into account the learning readiness of the Down syndrome children, due to their intellectual disability, language deficits, and their distraction, are integrated in an understandable and pleasant narrative and are structured in small steps, providing the necessary response time to prevent errors, when transitioning to more demanding activities.

The evaluation of its use showed that the "Bee-Bot" was able to develop strong interactions and increase their attention span, while the tasks in small groups strengthened the spirit of cooperative learning and learning by imitating their peers. Final positive achievements include increasing visuospatial memory span and acquiring robot programming skills [9].

4.3. ICTs tools for improving daily life skills

The problems in the expressive language of Down syndrome children, analyzed in detail above, are often loosely correlated with their level of intelligence, leading to their marginalization. However, by providing them with early and appropriate intervention, to develop their strengths, they can acquire the necessary skills to manage practical issues of their daily lives, so as to lay the foundations for an independent life with quality characteristics, within the community.

A. The "POSEIDON" project, with the support of technology, aims to improve motor skills as well as, time and money management, ensuring them a high degree of autonomy with planning and full control of their daily lives. The project was developed by the European Commission, from 2013-2016, with the participation of Norway, the United Kingdom and Germany.

The app through the main menu allows Down syndrome people to: a. navigate planned routes b. stay informed about scheduled events and add new ones c. watch instructional videos, uploaded by their caregiver from the respective app d. have access to the "money management training" application and e. make purchases through the "help with money management" app. All these applications are available in the languages of the countries that participated in the project and can be customized, based on the particular needs of each individual.

More specifically, to develop time management skills, the application uses an easy-to-use calendar, in which their caregivers, through an online platform, schedule users' meetings according to their needs.

Instructions are provided by video, recorded voice or sign language and with photos of the items needed for the specific meetings. Users receive an audio and visual reminder of the appointment or even an update on the weather forecast on their smartphone, while they have the ability to change or even delete a scheduled meeting.

To advance their motor functionality, through the “Route Creator” app, caregivers create routes, to which they can add images from different places, as well as, text and speech. Through the “Home Navigator system” application, on the computer, they have the possibility to practice various routes at home or by using the tablet to navigate the streets. Thus, they acquire the ability of orientation and autonomous movement outside the home. The caregiver has the ability to monitor the users’ location position - if they activate this function - and suggest important places on the map [164].

For money management training, a game was developed as a smartphone app, making it easier to understand the value of money and how to pay for selected products, in order to provide them with support for their daily purchases, as only 14% of them know the value of coins and banknotes. Through the online platform, caregivers create shopping lists, where they add images of the products and their prices. The users must choose, for each product displayed on the screen, the correct amount of money to pay for it. Between the price tag and the money display field, the amount due is displayed in colored letters, making it easier to recognize the digits.

The “Money Handling Training” app allows them to practice before going to the physical store, where they are supported by installing the “Shopping App” on their smartphone. The app informs them of the price of each product, the list of products they need to buy and their total cost, as well as, the type of coins and banknotes they need to pay.

Learning is provided through a simple interface in order to focus on the activity and in small steps, such as paying for a product initially, while there are relevant settings for more advanced users. The application provides positive feedback after the purchase of each product, as well as, at the end, after completing the shopping list [164-165].

B. The “Smart Angel” system is one of the most innovative technology tools, combining ICT with cloud technology and geolocation systems, and was developed in Liguria, Italy, in a two-year project, from 2013-2015, to support the development of the necessary skills for the autonomous movement of Down syndrome population. Their selective deficits, located in certain cognitive processes, make it difficult for them to move independently, through city streets and arrive at their desired destinations on time, as reading a map requires the operation of abstract thinking. On the contrary, it has been found that their learning is facilitated through practical situations, connected to their daily experiences.

This system supports users in moving independently outside the home, exploring new routes and managing their time properly, in order to reach their destination on time. However, as the application designed based on the educational approach of scaffolding, provides them with the possibility of assistance from the instructor, who discreetly monitors, through technology, their movements and guides them or intervenes in unforeseen situations.

In the initial stage of training, the development of basic user skills is attempted, through activities managed by trainers and provided in the form of serious games. In the next stage, a distributed intelligence system provides personalized support to the user, through scaffolding activities, which gradually subside as the user acquires the targeted skills.

The central platform, based on cloud technology, stores all data for users and connects all system components. In this way, instructors discreetly monitor, in real time, the location and activities of users on maps, through satellite geolocation systems, and intervene when it is necessary. In addition, by studying the data of the users’ movements, they understand their level of abilities and their needs and provide them with the necessary support. Through this smart app, which implements a blended learning model - scaffolding together with autonomy - users receive instructions, reminders, suggestions on their smartphone, gradually acquiring independent living skills, that boost their self-confidence: a. knowledge of the basic rules for safe traffic on city streets b. orientation skills c. ability to recognize and avoid their exposure to risk and d. ability to identify key elements that facilitate their autonomous access to the desired destination [157].

5. Discussion & Conclusions

Language development is the area of Down syndrome children that presents the greatest impairment, which is exacerbated over time, with the main feature of inconsistencies in the development of different language areas and processes and with higher performance in language comprehension and greater difficulty in the syntax production. At the same time, the cumulative effect of a set of factors - cognitive, linguistic and maturation - contributes to the manifestation of individual differences, displaying different linguistic patterns of strengths and weaknesses, given that children's growth and development is not the same in any person. Moreover, despite their observed delayed onset, their linguistic structures follow the typical order of occurrence, but at a progressively slowing pace - possibly due to their cognitive deficits - starting from the early years of their life and performing at the lowest level of formal variation. These findings, for slow but typical development, are reinforced by the Developmental Approach, which points out that all children cross similar developmental sequences (Hypothesis of the Same Developmental Sequence) and much more from an enlarged developmental perspective, that even individuals with organic etiology mental disabilities, such as Down syndrome children, follow the established principles of development and maturation, but at different rates (Different Rate Assumption) and with a lower final achievement level.

Therefore, all this is in line with what our research has shown, as the language development of Down syndrome children -mainly with mild retardation- was found to be qualitatively similar to younger children of typical development, equated to mental age (cognitive-developmental level). That confirms Lenneberg's (1967) view that "language development, in Down syndrome children, is a slow-moving copy of typical acquisition, similar in all respects, which differs only at the rate of acquisition" [4]. However, in information processing tasks, they differ qualitatively from the formally developing children, as these reflect the pace of cognitive achievement. Nevertheless, according to the hypothesis of "the physical variation" of the developmental model, some forms of intellectual disability are part of the individual variation of typical cognitive development. This finding is consistent with Fischer's words (1980), as saying that "dissimilarity is the rule of development" [166].

On the other hand, given the great heterogeneity of the Down syndrome population, more in-depth research is required of their cognitive and language skills, but also of the results of the provided education, based on the differentiated diagnosis of their linguistic profile. In addition, these findings suggest that, in order for early intervention language programs for Down syndrome children to be effective, they need to integrate the developmental sequence applicable to children with formal language acquisition, due to the similar trajectory in language acquisition. Furthermore, these programs, taking into account the need to acquire daily life skills, should incorporate educational activities to develop algorithmic and computational thinking, but also highly interactive educational robotics activities, that can become alternative educational tools for early intervention and effective rehabilitation, ensuring them an independent and active life in the community.

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