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Review

Impact of Assistive Technologies to Inclusive Education and Independent Life of Down Syndrome Persons: A Systematic Literature Review and Research Agenda

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Abstract: Since the beginning of the 21st century, the lifespan of people born with Down syndrome (DS) has increased. They now outlive their parents and rely on their relatives who usually sacrifice their own families to care for their disabled siblings. To reduce the pressure on families and the wider community, it is crucial to prepare DS people for independent life from early childhood. Emerging technologies can significantly support the process of acquiring the skills that are necessary for solving real-life problems at home and work. To assess their impact and estimate how much they are implemented in inclusive education, a review of 564 papers published after 2015 was done using the PRISMA review model. After gradual exclusion, 24 papers were used for the final review. Thematic analysis resulted in four themes with one common concept: variety. The results of examining the four research questions defined in the paper's background confirm that the synergy of emerging assistive technologies and inclusive education has the potential of becoming a very effective strategy for creating an independent life for DS individuals. Many questions remain open, mainly related to a DS persons' specific needs and capabilities. The acceptance of the proposed synergy will depend on them.

Keywords: assistive technologies; Down syndrome; functional skills; inclusive education; independent life

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1. Introduction

Down syndrome (DS) is among the most complex genetic disorders that occurs in 1 in 1000 to 1100 live births [1]. The life expectancy of these people has considerably increased, starting from 12 years in 1942, through 47 years in 2007, and reaching 60 years in 2020 [2]. In most cases, the care of these individuals is anticipated to be provided by their siblings [3]. To reduce the high stress of caregiving for aged DS people and to lessen the sacrifice of their own private lives, caregivers should prepare DS children for an independent life [4]. Regardless of various initiatives intended to support the gathering of the essential life skills, the impression is that barely one-third of the DS individuals from the US and the Netherlands were living independently by 31 years of age [5]. Our personal experience is not so optimistic. Namely, all the children attending the Day care center for DS children we collaborate with do not have sufficient life skills for a fully independent life. Their literacy is very low, disabling them from finding necessary information on the internet or traveling alone. Due to the COVID-19 pandemic, they missed almost a year of extracurricular activities in the center which additionally degraded their communication and practical skills.

DS people have delayed physical growth and mild to severe intellectual disability (ID). Their typical mental ability is below 10 years, and severe ID prevails among teenagers compared to younger children [6]. ID symptoms of DS children usually overlap with the symptoms of autism spectrum disorder (ASD), affecting poor expressive language and nonverbal social communication [7]. Language disorder is affected by their physiological difficulties in correctly articulating sounds [8]. Frequently, DS persons experience challenges in their cognitive functioning and they are more likely to develop Alzheimer's disease [9]. Speech unintelligibility decreases their intellectual, developmental, and cognitive abilities, resulting in poor communication [10]. It is additionally worsened due to impaired memory span, affecting their auditory-verbal memory [11]. Due to the lack of cognitive and visuoperceptual memory, combined with the inability to clearly express their needs, DS people sometimes get lost, even when they know the environment well [12]. Their delayed cognitive development affects motor functioning, including fine motor control, which is important when performing daily activities [13]. All these disabilities become more severe among DS adults because their physical health deteriorates faster than healthy people's. According to Picciotti et al. [14], their hearing declines, starting from 42.9% between 20 to 29 years to 90.91% between 50 and 59 years. Ophthalmological problems affect more than 80% of DS people, affecting their visual abilities [15].

Typical to all syndromes, DS people have multiple disorders and health issues that affect their life and education. To overcome some of them, DS persons attend speech therapy, physiotherapy, and occupational therapy. Their families or caregivers actively participate in their development. Despite all the efforts, DS persons usually experience serious problems comprehending the instructions they are exposed to [16]. On the contrary, they are keen to use mobile technologies [17]. This fact is a motivation to try to introduce familiar technological aids for daily-life activities as part of their learning process.

Although many experiments have been performed to improve the daily functioning of DS people, enabling them to enhance learning via interaction, it seems that there is no specific approach intended for this kind of disability [18]. Many assistive technologies have proved their usefulness in overcoming some of the physical challenges during learning processes, but none is DS specific only [19]. The major reason is that this syndrome embraces various intellectual, physical, and psychological problems, each of them treated with different technologies. The most frequently used assistive technologies encompass:

- Augmentative and alternative communication (AAC) systems that propose non-verbal communication methods [20] such as: digital technologies with text-to-speech software [21], communication boards [22], sign language [23], gestures [24], and facial expressions [25];
- Augmented reality (AR) that consists of computer-generated elements in the real world and virtual reality (VR) in a computer-generated environment where 3D motion graphics are simulated to look realistic from the user's viewpoint [26];
- Beacons, which are wirelessly connected devices that determine location and deliver content according to the location [27];
- Educational robots and simulators that enhance the ability to learn and communicate and increase motivation and concentration [28,29];
- Educational video games that introduce gamification and interaction for acquiring new knowledge and skills [30].

The authors believe that the potential of well-designated assistive technologies intended for DS children is immense, particularly when they are intended for gathering essential life skills and incorporated within inclusive education. To evaluate this hypothesis, based on the identified needs for conducting a systematic literature review in this area, and adhering to steps recommended by Borrego et al. [31], this paper addresses the following research questions:

1. What are the assistive technologies that contribute to the inclusiveness of children with Down syndrome?
2. To what extent do the assistive technologies support the activities of independent daily living?
3. What are the barriers to integrating assistive technologies in inclusive education for Down syndrome students?

4 Which factors can contribute to developing new assistive technologies that support the functional skills of Down syndrome children?

To answer these questions, a review of 564 papers published after 2015 was done using the PRISMA review model, as explained in Section 3.

By exploring the current state of knowledge in the field, we have demonstrated that the knowledge body of assistive technologies research lacks a comprehensive and systematic review that covers studies about the impact of emerging assistive technologies for DS children providing them independent life skills, including education inclusiveness. Therefore, this study aims to fill the gap in the literature and strives to help future researchers to get a better glimpse and insight into this domain. Moreover, it also identifies new directions for research.

Section 2 systematically introduces the background concepts and provides a brief elaboration of the candidate papers that are review papers that overlap with ours. Particular attention will be paid to observed gaps and limitations of already published relevant surveys that our work will also address and explain the added value of our approach. Then, in Section 3, a systematic explanation of the research methodology is presented. Section 4 introduces and briefly discusses the four themes that were identified during the systematic review of the papers that match the inclusion criteria. Section 5 elaborates on the research questions that were identified within the introduction section. Section 6 presents the conclusions, followed by Section 7 where prospective practical implementation of the findings and the future research directions are discussed.

2. Background

Functional skills are those skills that people need for an independent life. They are usually divided into practical life skills, functional academic skills, community-based learning skills, and social skills [32]. Practical life skills include the ability to walk, speak, communicate, self-feed, self-toilette, prepare a meal, or make simple requests [5]. They are usually gained by mimicking the activities of other family members or guardians. Simple instructions, and discrete but persistent support lead toward making life skills a daily routine.

Prajapati, Sharma, and Sharma [33] citing UNICEF, UNESCO, and WHO suggest that the core life skills embrace problem solving, critical thinking, effective communication skills, decision making, creative thinking, interpersonal relationship skills, self-awareness building skills, empathy, and coping with stress and emotions. They should be achieved as part of formal inclusive education. This ensures that students from different backgrounds have an equal opportunity to go to school, learn, and develop the skills they need and to benefit from each other [34]. By attending regular schools with peers of similar age, students with different disabilities improve their communication skills, feel a sense of belonging, create opportunities for developing friendships with each other, increase the desire to actively contribute to real-life activities, and improve their academic performance [35].

Assistive technologies refer to products or systems that support and assist individuals with disabilities [36]. They are used for improving communication, interaction, mobility, and execution of many daily activities at home, school, and work.

An Overview of Previous Research

The body of knowledge has already evidenced surveys in the domain of assistive technologies for inclusiveness, mainly focusing on their impact to overcome various physical challenges during learning processes. However, to the best of our knowledge, no review-based research has appeared synthesizing papers on assistive technology and its impact to assist DS children for independent life by acquiring the basic functional life skills.

Table 1 showcases the latest relevant systematic surveys along with their features, and differences in relation to our work. These differences provide the basis and the motivation to conduct a systematic review study on the impact of assistive technologies on DS children for independent life, including education inclusiveness. The type of synthesis provided through systematic literature reviews is required to help stakeholders (e.g., educators and researchers) focus on the areas that will provide the most benefit by making sense of the great amount of information presented from a large body of scientific research [36].

Table 1. (a) Summary of retrieved systematic surveys, their features, and differences with our work (part 1); (b) Summary of retrieved systematic surveys, their features, and differences with our work (part 2).

(a)

Title and Reference of Retrieved Survey	Features of Paper	Differences with Our Paper
Implementation of video modeling in the occupational therapy intervention process for children and adolescents with special needs: A scoping review [37]	The goal of the review is to examine the impact of video modeling and VR on gaining independence in life activities. The target group is children with IDD (Intellectual Disability Development) and with ASD.	DS children are not a target group of the review. Inclusiveness is not discussed.
Autism Guide: a usability guideline to design software solutions for users with autism spectrum disorder [38]	The aim of the paper is to extract the recommendations intended for the developers and designers who create software solutions for users with ASD.	Focused on ASD users. Assistive technology and inclusiveness are not discussed.
Access to assistive technology for people with intellectual disabilities: a systematic review to identify barriers and facilitators [39]	The paper reviews the factors that influence the access to assistive technologies intended for people with IDD in countries with lower income.	Concerned with the correlation between economic factors and accessibility. Inclusiveness is not discussed.
The use of social media and people with intellectual disability: A systematic review and thematic analysis [40]	The paper presents the results of a systematic review that evaluates the impact of social media and its use by IDD people.	Assistive technology and its impact on life skills are not discussed.
The Utilization of Augmented Reality Technology for Sustainable Skill Development for People with Special Needs: A Systematic Literature Review [41]	The paper reviews prior studies to decide the best ways of implementing AR technologies for gaining the essential functional skills that contribute to independent life.	DS persons are not the main focus of the review. Inclusiveness is not discussed.
Technology-enhanced and game-based learning for children with special needs: a systematic mapping study [42]	The main focus of this review paper is to evaluate technological support of educational activities for the youngest children with different disabilities, including DS.	Assistive technologies are primarily quantitatively assessed. Inclusiveness and functional skills are not discussed.
How people with intellectual and developmental disabilities on collaborative research teams use technology: A rapid scoping review [43]	The paper reviews technologies intended for remote research communication of people with IDD during health emergencies, with emphasis on the COVID-19 pandemic.	Mainly focused on teamwork. Inclusiveness, assistive technologies, and life skills are not discussed.
The Effects of Technology Supports on Community Grocery Shopping Skills for Students With Intellectual and Developmental Disabilities: A Meta-Analysis [44]	The paper examines the impact of traditional technologies that are used during occupational therapy of young people with IDD.	Inclusiveness is not discussed. Assistive technologies embrace audio, video recorders, and flashcards.

(b)

Title and reference of retrieved survey	Features of paper	Differences with our paper
Systematic review: Need for high-quality research on occupational therapy for children with intellectual disability [45]	The paper reviews medical electronic databases that present the experience of implementing occupational therapy for children with ID.	Mainly focused on everyday activities. Assistive technologies and inclusiveness are not discussed.
Systematic Review of Research on Augmentative and Alternative Communication Interventions for Children Aged 6–10 in the Last Decade [46]	The paper presents various assistive technologies, most of them AAC intended for very young children with complex communication needs (CCN), including a few DS children. Inclusiveness is researched.	The goal was to present and evaluate the interventions for CCN children. It does not present any specific assistive technology. Life skills are not discussed.
New and emerging AAC technology support for children with complex communication needs and their communication partners: State of the science and future research directions [47]	The paper examines AAC technologies for language learning trying to predict the challenges based on previously published research evidence. Target groups include cerebral palsy, DS, IDD, and ASD.	No search criteria and protocols were defined, and no repositories were explored. Inclusiveness and assistive technologies are not discussed.

Table 1. *Cont.*

Designing effective AAC displays for individuals with developmental or acquired disabilities: State of the science and future research directions [48]	The paper reviews VDSs and grid displays that are used to increase visual attention and performance of children with IDD and adults that acquired various disabilities.	Inclusiveness and assistive technologies and inclusiveness are not discussed. Life skills are mentioned but not elaborated on.
Pedestrian navigation and public transit training interventions for youth with disabilities: a systematic review [49]	The paper explores several applications that help people with different disabilities improve their navigation skills and safety in public transport.	Inclusiveness and assistive technologies are not discussed.
Effectiveness of pediatric occupational therapy for children with disabilities: A systematic review [50]	The paper reviews occupational therapy of young children with more than 10 different disabilities, including DS.	Inclusiveness, assistive technologies, and life skills are not discussed.
Implementation of inclusive education for children with intellectual and developmental disabilities in African countries: a scoping review [51]	The aim of the paper is to review five academic databases in order to improve understanding of inclusive education and extract the most convenient that will be later implemented in Africa.	Mainly concerned with the promotion of inclusive education. Technologies, including the assistive ones, are not discussed.
Using technology in special education: current practices and trends [52]	The paper studies the following aspects: the context of technology use, learners' characteristics, needed interventions, technology characteristics, and the outcomes.	Assistive technologies are examined in the light of the context they are used in. Inclusiveness is not discussed.
eHealth in the support of people with mild intellectual disability in daily life: A systematic review [53]	The paper examines whether eHealth can in parallel with the healthcare electronic processes also offer opportunities to support people with mild IDD in daily activities.	Mainly concerned with the use of eHealth to support persons with IDD. Assistive technologies and inclusiveness are not discussed
Technology-Enhanced Support for children with Down syndrome: A Systematic Literature Review [54]	This paper presents a systematic literature review on technology-enhanced support for DS children and young people who match the mental age of children considered neurotypical.	Not specific to the factors contributing to assistive technology development for inclusive education Does not emphasize specifically in which field it supports DS children.

3. Methodology

To conduct this SLR (Systematic Literature Review) study, we applied the guidelines indicated in [55]. The primary focus of SLR is the identification of best practices based on empirical evidence. This method is characterized by narrow and very specific questions and follows rigorously well-defined steps. The studies are explored in detail regarding the quality, and by being systematic, it strives to eliminate potential biases stemming from the review process. Additionally, it includes the adoption of a structured and progressive process and the construction of a research protocol [55–58].

3.1. Search Strategy

The online JabRef ® citation and reference management software was utilized during the article search and selection following the PRISMA approach. The entire procedure depicting the search strategy is illustrated in Figure 1.

As highlighted in [55], the research protocol development, the definition of the research question and keywords, and the identification of bibliographic databases are conducted during Stage 1. The following online research databases and libraries have been used for the search purpose: ACM DL, IEEE Xplore, SpringerLink, Wiley, Scopus, and Web of Science.

We employ the PICO (Population, Intervention, Comparison, Outcome) framework to design a comprehensive set of keywords, as shown in Figure 2. As suggested by Gianni and Divitni [59,60], we also include the Context section in the PICO framework to avoid skipping potential important studies.

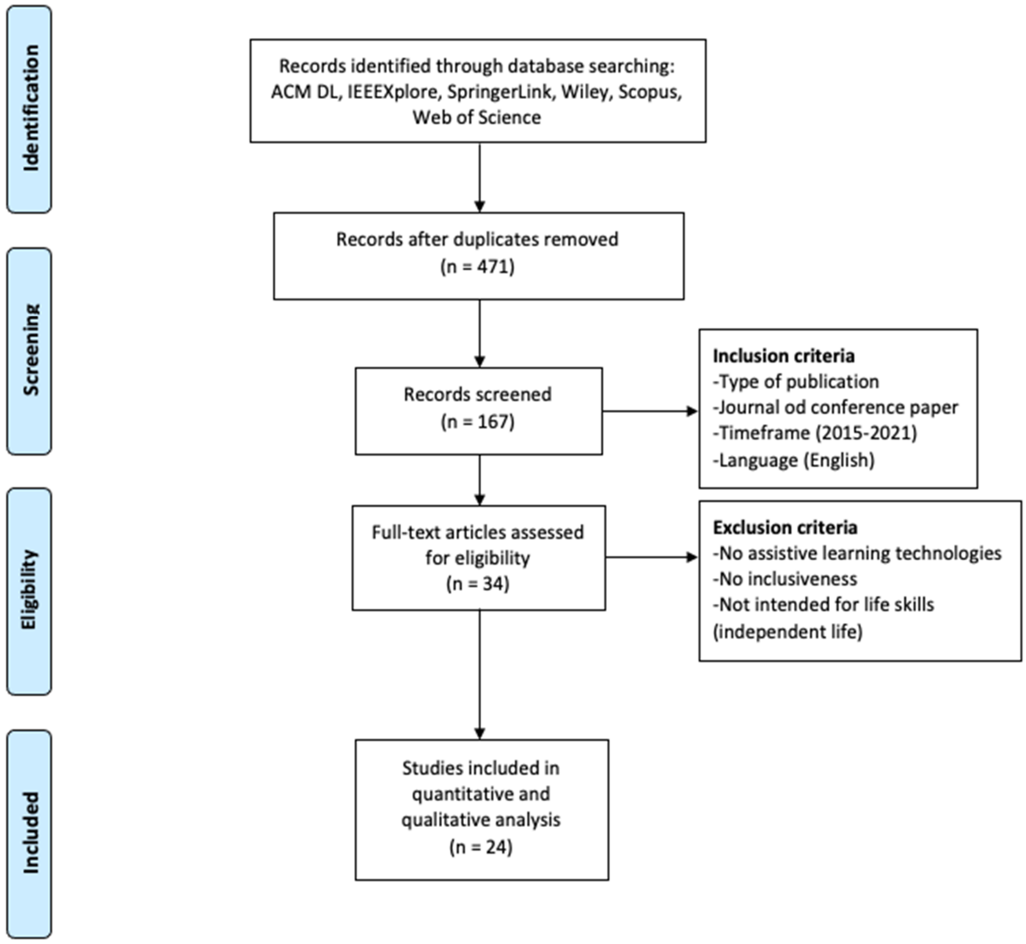

Figure 1. PRISMA model.

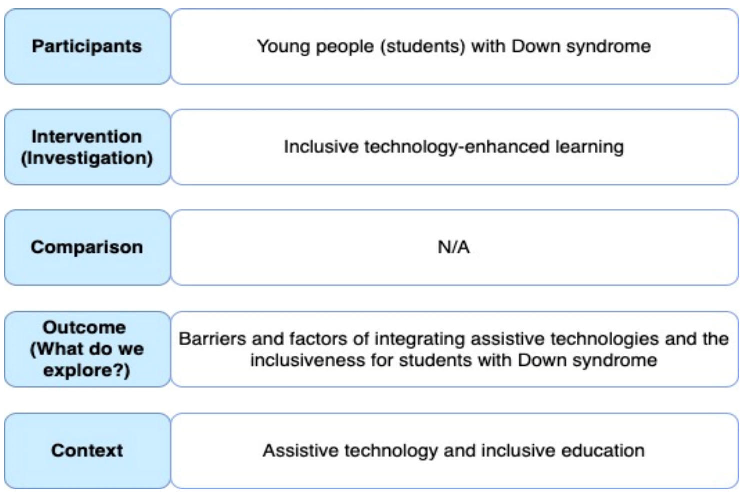

Figure 2. PICO(C) driven keywords framing.

In Table 2 we present the final search keywords in conjunction with PICO(C) applied in the study.

Table 2. Search string used in this study.

Context	("assistive technology" OR "accessible technology") AND ("inclusive education" OR "special education") AND ("Down syndrome" OR "disabilities")
	AND
Intervention (Investigation)	("inclusive") AND (technology-enhanced learning" OR "learning technologies" OR "computer supported learning" OR "game-based learning")
	AND
Outcome (What do we measure or explore?)	("inclusive classroom" OR "special education" OR "mainstreaming in education" OR "individualized education")

As of January 2015, the search in Stage 1 yielded 564 papers, which were organized and tabulated according to publication venue, type (i.e., journal or conference), database source, and year of publication. Table 3 presents the total number of selected studies distributed per bibliographic database in the initial stage and the final relevant studies included in the analysis.

Table 3. Studies found in different repositories.

Online Research Databases and Libraries	Initial Findings	Included Studies (Stage 4)
ACM DL	20	4
IEEEXplore	74	5
Scopus	244	5
SpringerLink	149	3
Web of Science	10	4
Wiley	67	3
Total	**564**	**24**

Screening refers to Stage 2 of the search strategy process and involves the application of inclusion criteria. At this stage, the relevant studies were selected based on the following criteria: (a) type of publication needs to be a peer-reviewed journal or conference paper, (b) papers should have been published between 2015 and 2021, and (c) papers should be in English.

After we applied the mentioned criteria, out of 471 papers, a total of 167 records were accepted as relevant studies for further exploration and screening. It is worth mentioning that we did not include papers which were missing a full text and written in a language other than English for analysis.

3.2. Identification of Relevant Studies

In Stage 3, the exclusion criteria were applied by eliminating studies that were not about assistive technologies and education inclusiveness, and those which did not highlight independent life. At this stage, all the titles, abstracts, and keywords were examined to determine the eligible papers for the next stage. In total, 24 papers were selected to be further included in the analysis.

Figure 3 shows the distribution of studies amongst the 24 papers; 18 were journal papers while 6 belonged to conferences. Figures 4 and 5 correspondingly show the number of selected papers published in journals and conferences published between 2015 and 2021.

During this search, we identified journals that support this domain, and these are shown in Table 4. This information can help future researchers when publishing their research in the domain of assistive technologies for DS children.

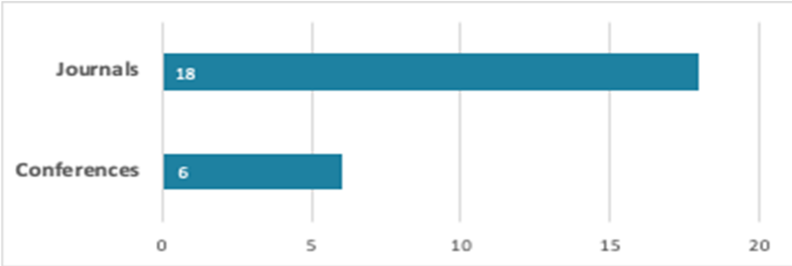

Figure 3. Distribution of the relevant studies (2015–2021).

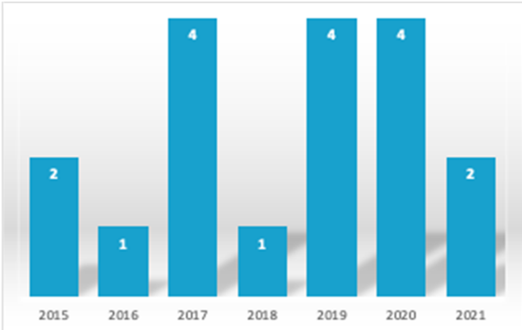

Figure 4. Relevant studies published in journals (2015–2021).

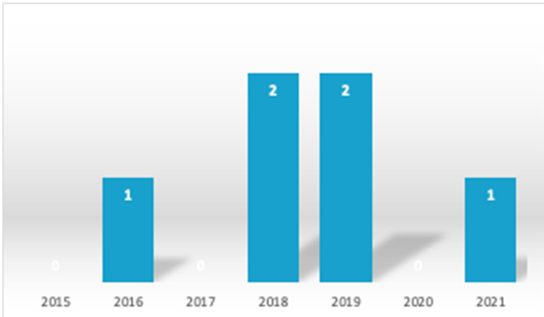

Figure 5. Relevant studies published in conferences (2015–2021).

Table 4. List of journals and number of relevant studies found.

Name	Publisher	Count
IEEE Access	IEEE	3
Computers & Education	Elsevier	1
Universal Access in Information Society	Springer	2
Multimedia Tools and Applications	Springer	1
British Journal of Educational Technology	John Wiley & Sons	2
Journal of Computer Assisted Learning	John Wiley & Sons	1
Behavior Modification	Sage	2
Health Informatics Journal	Sage	1
International Journal of Human-Computer Interaction	Taylor & Francis	2
Augmentative and Alternative Communication	Taylor & Francis	1
Wireless Communication and Mobile Computing	Hindawi	1
Problems of Education in the 21st century	Sci. Educologica	1
Health Informatics Journal	Sage	1

Table 5 shows the year wise summary of the papers, their types, and publishers between 2015 and 2021.

Table 5. Summary of the relevant studies distributed according to the year of publishing.

Studies	Year	Type	Publisher
[61]	2015	Journal	Springer
[25]	2015	Journal	IEEE
[30]	2016	Journal	Elsevier
[62]	2016	Conference	ACM
[63]	2017	Journal	Hindawi
[64]	2017	Journal	Taylor & Francis
[65]	2017	Journal	IEEE
[66]	2017	Journal	John Wiley & Sons
[67]	2018	Journal	John Wiley & Sons
[68]	2018	Conference	ACM
[69]	2018	Conference	IEEE
[70]	2019	Journal	Scientia Educologica
[71]	2019	Journal	Springer
[17]	2019	Journal	John Wiley & Sons
[72]	2019	Journal	Sage
[73]	2019	Conference	ACM
[27]	2019	Conference	IEEE
[74]	2020	Journal	Taylor & Francis
[75]	2020	Journal	Springer
[76]	2020	Journal	Sage
[77]	2020	Journal	IEEE
[78]	2021	Journal	Sage
[79]	2021	Journal	Taylor & Francis
[80]	2021	Conference	ACM

3.3. Limitations and Threat to Validity

Any research work involves a series of limitations. When assessing this systematic literature review, there are several factors that should be considered, as they can potentially limit the validity of the findings. These factors include:

- Only papers written in English were selected for the study. While searching the research databases, we found related articles in other languages; those articles are not included.
- The study includes papers collected from the six digital research databases shown in Figure 1. Thus, we might have potentially missed papers having been indexed in other digital libraries.
- For this study, only peer-reviewed journal articles and conferences were selected. Scientific studies that are not peer-reviewed were not included. This includes short articles, experience reports, and assimilation studies, as they usually present work in progress or preliminary studies whose relevance in the field is considered low.
- We did not include papers published before 2015 since our search did not yield enough relevant studies that were in the context of our study and which could have provided us with enough indication to answer the research questions, assess the evidence

critically, and draw conclusions accordingly. Therefore, only works published between 1 January 2015, and 25 November 2021, were selected in this study. We highlight that there may have been conference papers presented before 25 November 2021, that were not published by the cut-off date for this study and that they were not included in our literature review.

4. Thematic Analysis

The theoretical approach to thematic analysis was performed according to recommendations described by Braun and Clarke [81]. In general, this technique comprises two main steps: first, reading all papers to extract themes, and second, classifying the identified themes. Moreover, this process is characterized by the six phases guide: familiarizing with data, generating initial codes, searching for themes, theme review, defining themes, and naming themes. In our case, the overall process resulted in four themes, each discussed in detail in the upcoming sections.

Themes were identified to capture important patterns across and within the 24 papers. Discussion took place between the three authors to finalize and name the themes until the agreement was reached. Furthermore, our findings suggest that all the four themes illustrated in Figure 6 can be united with one word only: variety. Once the list of the relevant studies and the themes was identified, the next step was to elaborate and analyze the themes in order to answer the research questions.

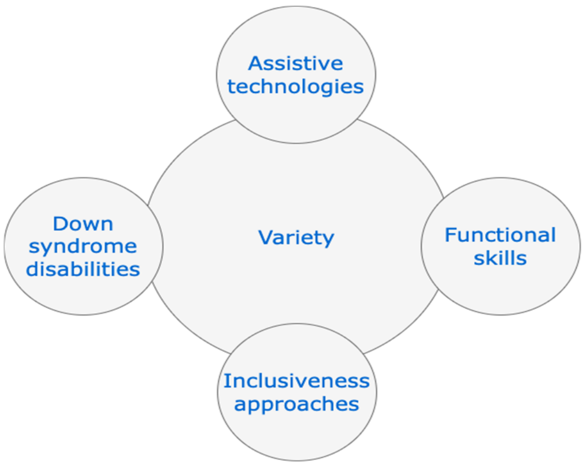

Figure 6. Variety as a common concept of the four themes that emerge from the discussed papers.

4.1. Theme 1: Variety of Disabilities

According to Merriam Webster's website (accessed on 03 December 2021), syndrome is "a group of signs and symptoms that occur together and characterize a particular abnormality or condition". The definition itself includes the variety of signs and symptoms that were explicitly related to DS.

Intellectual and developmental disabilities are the major symptoms that are explored in the following works: [25,30,62,65,70,75–79]. They address different problems related to DS adults and students such as: performing work tasks [27,30,74]; obtaining independent life skills [25,75,77]; improving long-term memory [76] and sensory stimulation [65]; experience of performing several of these, and finally; evaluation of vocational training [62].

Support of labor activities is implemented with three different approaches: by frequent repetition of learned labor skills [74], gamification of simple job skill acquisition [30], or enhancing orientation [27]. Life skills including shopping, social interaction, and job interviews [25] are additionally enhanced by eye-hand coordination skills that are crucial to increasing literacy skills [75]. Particularly important is the direct involvement in these activities, implementing a hands-on approach [77]. By gaining these skills, DS persons with mild IDD become more competent and their self-confidence increases [78].

Cognitive and memory impairments are also common, and they are examined in more detail in the studies: [17,27,61,63,64,67–69,71,73,76,79].

Selected papers cover the complete life cycle of improving these related impairments, starting with the creation of the didactic scenario intended to support educational intervention [68], through planning innovative strategies [73], designing of the digital assistant [79], customization of user-friendly environments to support learning [71] and supporting learning with board [61], tablet [66,67], video [64] and mobile games [17].

Speech and communication disabilities are the main focus of the studies: [25,68,74,75]. To facilitate communication and improve speech ability, these papers suggest various strategies and tools, such as educational robots [68], visual display scenes [74], gesture-based video games [75], and AAC systems [25].

Orientation is treated as a major impairment in the papers: [27,65,75]. Many DS people have low energy, they do not notice or process the information they receive from their senses and need more sensory input to become organized and focused [65]. Therefore, they need eye-hand coordination support [75] and assistance in performing tasks [27].

Another group of researchers conducted relevant work to study persons having complex communicative needs by implementing aided augmented communication systems [72]. Finally, neurodiversity conditions with variations in the abilities of individuals in cognitive, motor, and communications skills are addressed [80].

In several of the surveyed papers, IDD overlaps with cognition [76,79], speech impairment [74], or with orientation [65]. Cognition and speech disabilities [68] and cognition and orientation [27] also co-occur. The most specific is the coincidence of the three impairments: IDD, speech, and orientation, which are the main topic of the research by Caro et al. [75]. Moreover, neurodiversity [80] is closely related to cognitive, cognitive, and motor impairment. In total, one-third of all the selected papers cover several symptoms in parallel, proving that they should never be treated in isolation.

4.2. Theme 2: Variety of Assistive Technologies

Intended to support persons with various disabilities, the assistive technologies for DS students are very variable. The most widely surveyed is AAC. AAC based systems are developed in the projects reported in the papers: [25,74]. They are primarily related to speech and cognitive disabilities. While AAC video visual scene displays are implemented to stimulate communication and participation [74], communication boards and high-tech electronic communication devices are predominantly carried out in educational sessions and environments [25]. Both systems are suitable for adolescents with more severe communication needs.

VR, which can be enhanced by AR, is the main technology deployed to support people with various disabilities, including DS, across their lifespan [25]. The vocal production effect, referring to memory enhancement via vocally produced words was successfully used for improving long-term verbal memory by presenting familiar and unfamiliar images, familiar words, and short written sentences and saying the words or phrases aloud [76].

Digital assistants are the main technology to support DS people in developing their life plans [79]. Moreover, they can also be used to help them learn basic arithmetic operations through digital boards [61].

Edutainment as an educational form of using video games is presented in the studies: [30,64,67,69,71,75]. The first paper presents a platform for delivering accessible games for enhancing cognitive learning and training [71]. Two valuable video games support eye-hand coordination [75] and speech skills [64]. A small-scale game “Home game” is an augmented table game that can be played with printed cards and by using touchscreen applications [67]. In a contrast to this game for children, serious games for job training also use the edutainment approach [30]. Finally, cognitive computer games were used to improve attention span [69].

Robots, beacons, and authoring systems are examined in the papers: [25,27,65,68,78]. Research related to these technologies starts with an overview of avatars, humanoids, robots, and VR for obtaining life skills [25]. By using a Lego Wedo 2.0 kit, an educational robot motivates DS children to participate and increase their performance, as presented in the paper [68]. Intended for mobile use, Android devices combined with beacon technology assist DS persons complete different orientation tasks [27]. The web platform consisting of games and virtual scenarios that assists DS persons to participate in various daily living leisure activities is introduced in the paper [78]. Accessible wizards that cover several assistive technologies are the main topic of the paper [62]. Further research [65] introduces an authoring tool intended for children with sensory processing disorders and teaches them to recognize coldness, hotness, vibration, and firmness perception, as well as animal sounds.

Challenges and opportunities regarding hands-on experiences with assistive technologies for people with intellectual disabilities are identified in [77]. The authors show that comprehensive and accessible communication channels play a major role while performing experiments through assistive technologies.

The variety of assistive technologies is even greater than it is presented in this paper because there are many different features that further enrich the assistive and accessible support of DS people under the umbrella of one technology. It is fascinating that the majority of presented assistive systems in the selected papers, such as AAC, AR, and VR are cutting-edge technologies, proving that their development supports the innovative trends.

4.3. Theme 3: Variety of Functional Skills

The reviewed papers included in this SLR introduce a variety of learning activities and tasks intended to enable the gaining of the essential functional skills important to capacitate them for an independent life. They all present mutually related groups of experiments. To support training and integration, two labor tasks: photocopying and document archiving were deployed as smartphone applications [63]. VSDs enhanced by ACC were introduced as an intervention to help students with DS complete steps of specific everyday activities, such as packing backpacks with food [74]. Another valuable contribution to gaining functional skills is the Web-based course that helps IDD persons repeat some working activities in horticulture that they previously acquired during practical teaching [70]. They include planting seeds in pots, planting seedlings in pots, watering using a watering can, and weeding the flowerpot. Games were used to strengthen cognitive abilities and fine motor development through images for painting and the work of puzzles [73]. Serious games for the job training cover eight games: apple packaging, hydroponics, cafeteria food distribution, pen assembly, wood work, mail delivery, ATM, and grocery assistant [30]. Digital assistants for developing life plans enabled four small experiments: proposing a question, discussing their own past and present, a quiz, and brainstorming about their future [79]. "Home game", which consists of several mini games: home presentation, locate the room, place an object, find the wrong object, find the correct sentence, and quizzes, is also a kind of a game that supports the gaining of life skills [67].

Although the number of papers that deal with the essential functional skills and their gaining is smaller compared to the whole list of selected papers, the exhaustive and ambitious approach implemented to create the experiments, and the overall success, shows promise that various assistive technologies can become the driving force to supporting fully independent life, and consequently, to increase the lifespan of DS people.

4.4. Theme 4: Variety of Inclusiveness Approach

The selected 24 papers propose a wide variety of different inclusiveness approaches, including the augmented tabletop game for children with cognitive disabilities [67], the authoring system for personalized sensory stimulation [65], virtual reality and robots [25], eye-hand coordination and a pre-literacy skills [75] digital whiteboard interface that support DS students learn addition and subtraction [61], beacon technology that supports DS persons on orientation tasks [27], and data-driven wearable smartwatch sensors [80]. These were mainly used in regular schools by children with different disabilities, including Down syndrome, as well as by their mates with no disabilities. Those technologies that were not tested in inclusive classrooms were part of the technology-enhanced education in special schools for the children with more severe impairments [25].

5. Findings of the Research Questions

In the following sections, we elaborate on the findings from the research questions that were crucial for this systematic review.

5.1. RQ1: What Are the Assistive Technologies That Contribute to the Inclusiveness of Children with Down Syndrome?

The educational tool “BeeSmart” introduced in the paper [75] is a tool for supporting DS children to strengthen their eye-hand coordination by playing games that stimulate body mobility through an immersive experience and pre-literacy skills through pictorial representations.

Authors in paper [27] propose a system based on smartphones and beacons for assisting people with cognitive disabilities in relation to their social inclusion. In everyday life, it enables spatial orientation, and in the labor field, it serves as task training.

The importance of an adequate interactive digital whiteboard interface to support DS students in their learning of addition and subtraction is emphasized in [61]. Visual aids such as graphics, balls, and fingers are identified as important aspects because students can rely on the embedded aid strategies and fewer abstractions.

In the paper [78], the authors introduce an e-Training platform aimed at teaching key competencies, including promoting autonomy, self-awareness, and self-management, developing social and digital skills, and enhancing transversal skills.

In another study [25], the authors introduce VR and robots and examine the potential of different applications, such as virtual supermarkets, virtual cafés, social cognition training, and virtual reality job interview training in obtaining independent living skills.

Moreover, the study [65] introduces an authoring tool intended for children with sensory processing disorders, including DS. To overcome noticeable problems of these children, five applications for haptic devices have been developed enabling perception of coldness, hotness, vibration, and firmness perception, as well as animal sound recognition. The evaluation included 112 summer camp children with sensory processing disorders, proving that the personalized content is essential for sensory stimulation education and that the applications are easy to use.

Additionally, an analysis of data from three iterative cycles of designing a tablet app for children with Down syndrome to support their awareness of quantity through an inclusive game was conducted [66]. Supporting children’s learning by enhancing their mathematical skills demonstrated that with adjustments to the app design, learners can be actively engaged to the point of exceeding expectations. Moreover, this research sheds more light on the situations in which children with DS disengage from learning.

All the presented projects were performed and evaluated as part of regular educational activities among children with and without disabilities, reinforcing the initiative of including technologies in inclusive schools. Specific assistive and accessible features of these technological devices proved their great potential to enable impaired children to participate in the carefully and systematically designed activities by experienced pedagogues.

5.2. RQ2: To What Extent Do Assistive Technologies Support the Activities of Independent Daily Living?

There are several interesting projects that introduce the impact of introducing assistive technology as successful support of achieving the necessary skills for an independent life. For example, the paper [63] proposes a case study based on mobile phones and QR Codes to assist individuals with cognitive disabilities in their labor training and integration. It is a fully functional mobile application for Android smartphones and offers step-by-step guidance, establishing a learning method through task sequencing. Smartphones are used as prompting devices and performance recorders. First, the caregiver defines the task, once the task definition is ready, a QR Code containing its information is printed and tagged in a proper place (e.g., close to the washing machine for the "doing the laundry" task). Users open the application on their phones, point at the tag, and follow the steps to complete the task. From the comparative analysis done between users who use the Assist T-Task as support and users who use paper support, it was identified that users who use Assist T-task needed less time to finish the task, fewer mistakes, and fewer help requests.

In another research work, which is presented in the paper [67], the authors introduce the augmented table game "Home game" based on a small-scale "Farm game". It can be played with printed cards and as an application using touchscreen devices. "Home game" consists of several mini games. It was tested with 20 students with cognitive disabilities. Students enjoyed the game, learned it easily, and reacted with enthusiasm. No boredom or frustration was noticed. The overall success rate was 86%. Erroneous interactions and wrong answers were significantly lower when children were given hints.

The use of serious games intended to support the acquisition of functional skills necessary to perform two everyday activities, apple picking and growing plants without soil, were proposed in the paper [30]. Both games last 5 min, the first one includes the wrapping of apples and the second one the wrapping of all the plants. Playing the games prior to performing the task increased performance speed and improved the accuracy of hydroponic tasks. The main advantage of this approach is the acquisition of simple job skills using video games. It improves self-confidence, causes positive feelings, and increases the motivation to perform vocational tasks.

These successful case studies, together with the examples introduced in theme 3, prove that emerging assistive technologies can become a solid groundwork for building applications that might prepare the impaired people, including those with DS, gain the most important functional skills. Half of the papers that cover this aspect were published after 2020, proving that the interest to prepare the impaired persons for a fully independent life with technological innovations is becoming more attractive for researchers and pedagogues.

5.3. RQ3: What Are the Barriers to Integrating Assistive Technologies in Inclusive Education for Down Syndrome Students?

Apart from the obvious benefits, most of the studies that were practically implemented revealed a variety of barriers to integrating the emerging technology or the inability to incorporate them into inclusive education. These include the need for constant supervision [70], thus disabling full independence; the need for customization for DS persons [25]; comprehension problems triggered by the significant difference with traditional technologies [30]; an unclear interface [67] that causes confusion and drop outs [65,75]; reliability problems of used assistive technology [61] that significantly disables its inclusiveness [25], and also imprecise assessment of the approach due to very few participants that were included in the experiments [75,79].

This exhaustive list of disadvantages noticed in almost half of the reviewed papers confirm the fact that the integration of new assistive technologies, particularly in inclusive education, is still in its infancy. The creators of these applications are aware of the deficiencies and promise to overcome them in the next edition.

5.4. RQ4: Which Factors Can Contribute to Developing New Assistive Technologies That Support the Functional Skills of Down Syndrome Children?

Many studies have pointed out the importance of various factors that can contribute to developing appropriate assistive technologies for supporting various functional skills. The application based on smartphones and beacons serves as a guide for specific task executions supported by visual and pictorial support which are intended to be clear and understandable [27]. After learning to use the application, the user begins to have autonomy in the execution of that task, making this application a new way of learning.

Another paper [25] introduces two main approaches to using AAC systems: communication boards and high-tech electronic communication devices. The authors propose a new AAC system consisting of a communication sheet, symbol recorder/player system, and communication protocol. The prototype was tested by eight children and four of their supervisors. The AAC system has a very intuitive way of use, low weight and manageability, low price and low power consumption, wireless communication features, and the ability to adapt to different educational sessions and environments.

Some other scholars also examined the production effect (PE) paradigm, referring to memory enhancement via vocally produced words [76]. The effect of presenting familiar and unfamiliar images, familiar words, and short written sentences and saying the word or the phrase aloud was compared with no-production. The results of implementing PE were significantly superior, except with the unfamiliar words. The experiment was not supported by a specific assistive technology but inspires the creation of such an application for young people with DS.

A digital assistant that helps DS people develop a life plan announced several subjective and objective advantages [79]. The advantages appreciated by DS people were the effectiveness, efficiency, interactions to accomplish the tasks, satisfaction, and usability. The objective advantages embrace the support of choice options and decision-making capacity; increased self-knowledge and self-determination; increased self-esteem and self-efficacy; and improved well-being. These are the main factors that will contribute to the development of new assistive technologies that support the independent lives of DS people, particularly when they will no longer be able to depend on their parents.

All the presented technologies are emerging and include the most sophisticated technological advancements that will likely be crucial in supporting DS persons to overcome their intellectual and cognitive disabilities while they still grow, as well as the age-related vision and hearing disabilities. New technologies will undoubtedly be designed in the near future. To advance them, it is crucial to first advance DS research that still has too many scientific gaps [82].

6. Conclusions

Since the beginning of the 21st century, the lifespan of people born with Down syndrome has significantly increased. As DS people mature, their older parents or guardians may already need self-support, so DS people need to be as independent as possible to avoid becoming a burden on their relatives and society.

Similar to most post-millennials, i.e., young people born after 1997 [83], DS persons are fascinated by technology gadgets and they have been familiar with mobile devices since their early childhood. Instead of using technology only for leisure, if powered with appropriate accessibility features, it can become their key ally in acquiring the habits and skills necessary for independent living. Gaining essential functional skills should be organized within regular education, together with the school mates of similar age.

To evaluate the assistive technologies that can contribute to the inclusiveness and independent life of DS people, this systematic literature review was performed, revealing several core concepts.

There are many powerful assistive technologies that can be successfully used by DS people. None was developed for only them, mainly because DS is a complex genetic disorder that unites different impairments, with mild to severe intellectual and developmental disorders as the only common ones. However, most of the reviewed assistive technologies were accepted with enthusiasm, particularly video games and easier problem-solving tasks. These contributed to better orientation, eye-hand coordination, and performing of some daily activities of DS children and adults. Successful execution of the intended tasks increased their self-esteem and self-efficacy.

In parallel with the variety of assistive technologies, according to this systematic review, very few of them were included in inclusive education. Wherever they were evaluated by children with and without disabilities, most of the developed technological solutions have proved their potential for problem solving, including everyday activities. The benefit of using technological solutions was noticed among all children, no matter their abilities. Usually, they were capable of performing the same activities faster and with better accuracy.

Among the selected papers, less than one quarter introduces technological support in performing functional life skills. Most of the applications are video games or personal assistants, proving that the potential of assistive technologies is not sufficiently used to contribute to enabling an independent life.

7. Further Directions and Future Research Agenda

Our main inspiration to conduct this study derives from the intention to try to incorporate some of the discovered assistive technologies in the Day care center in Skopje. After a successful fundraising project initiated by Davor, a software developer who contributed to the creation of educational games for DS children [84], the center purchased 10 tablets and the games were installed. The initial fascination with playing them was abruptly stopped due to the COVID-19 pandemic. Hopefully, after almost two years of complete inactivity, the center is now working at full power. Their main activities are currently related to sports activities, dancing, discovering the beauty of nature, and learning how to use medicinal plants. After finishing these activities, they will concentrate on regaining skills in cooking and preparation of handicrafts. Pedagogues from the center have approved the implementation of hands-on assistive technologies as a complement to traditional face-to-face teaching. We all strongly believe that DS children will be enthusiastic to use them, as they were with the educational games. Their feedback will be crucial to carry on with the further investigation of assistive technologies and their contribution to gaining the necessary skills for a fully independent life.

In parallel with the practical implementation of the acquired knowledge based on this systematic literature review, we would like to explore the opportunity of introducing assistive technologies into inclusive education, with a particular focus on children with Down syndrome. In order to achieve this ambitious goal, several important steps should be undertaken, starting with a review of inclusive schools that are actively implementing assistive and accessible technologies to overcome the barriers caused by Down syndrome. Based on the findings, we will extract the most promising technology-enhanced systems, localize them to our environment and first evaluate them in the Day care center. The protégés in this center are young teenagers who are still attending inclusive primary schools, but at the same time, they are very experienced in participating in various projects that significantly improved their performances. The assistive technologies they accept with pleasure will be suggested to selected schools that already actively collaborate with the center. It will be the first step towards full e-inclusion.

Although still in its infancy, the impact of implementing assistive technologies to support education and the independent life of Down syndrome persons is promising. To really enjoy their power, assistive technologies should become part of national inclusive policies. They should also be included in health and welfare schemes. Teaching assistants and families should also be trained to use the technology, to support the familiarization with the first assistive solution; one successfully mastered technology will become a stimulus for many new ones. If properly designed and implemented, assistive technologies will become the most powerful partner of many families with children born with Down syndrome.

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