Systematic Review of Educational Technologies for Children and Adolescents with Down's Syndrome: Trends, Patterns, and the Role of Relational Support

Yanchun Du[1†], Boxing Zhang[2†*]

[1]*Basis International School Shenzhen, Shenzhen, China*
[2]*Suzhou North America High School, Suzhou, China*
†These authors contributed equally to this work and should be considered co-first authors.
**Corresponding Author. Email: boxingzhang695@gmail.com*

Abstract: This paper reviews the research on the use and development of educational technologies for children and teenagers with Down's Syndrome. Many believe in the effectiveness of this approach due to the inability of conventional methods to support this population. Given that conventional educational methods often do not adequately support this population, we hypothesize that integrating educational technologies could offer more effective learning solutions. To verify this hypothesis, we screened 132 studies available on EBSCO, and finally got 31 studies is fully supported by our findings. The results of these studies show that there are many benefits of using technological tools to support the learning of children with Down's Syndrome. However, our findings illustrate almost all the existing educational technology studies (85%) investigating youth with Down's Syndrome investigate human-to-human relationships that include a technological component rather than studying with technology alone. This finding supports the credibility of Lev Vygotsky's Sociocultural Theory of Learning in real-world educational settings. Indeed, this review finds that many studies systematically underestimate the positive impact of integrating technology and relationship-based interventions, indicating the need for further research. Ultimately, it is the combination with human capital that can unleash the full potential of educational technologies and yield the most positive outcomes for children with Down's Syndrome.

Keywords: Down's Syndrome, Systematic Literature Review, Technologies, Positive, Youth

1. Introduction

Down's Syndrome is a genetic disorder caused by the presence of an extra copy of chromosome 21. The disorder is associated with the appearance of certain intellectual disabilities, developmental delays, and distinctive physical features. Among the most common symptoms are deficits in cognitive functions, delayed speech, low muscle tone, and typical accompanying physical appearances, such as a flat nose bridge, short fingers. The lifelong challenges of the condition create special educational needs such as learning for a longer period, practice pressure-free learning, and teaching plans to avoid optimizing difficulties.

Children and young people with Down's Syndrome (DS) experience many learning difficulties. This population often has unique developmental and cognitive delays, causing a deficit in cognitive

processing necessary to acquire information and skills [1]. Conventional approaches to teaching and learning frequently fail to support this population, leading many to become more interested in how to address this problem through the application of educational technology.

Common educational technologies supporting students with Down's Syndrome include communication devices, such as Picture Exchange Communication System, computer-assisted learning, interactive whiteboards, speech recognition, and adaptive learning systems. First, communication devices and computers with learning software applications help the students with a multi-sensory learning experience and retaining focus. Second, the devices assist students in learning and communication by transmitting and sharing digitally supportive pictures, written and spoken instruction, and other relevant materials. Thus, their learning is supported by visual materials and communication advantages, which help them actively participate. As a result, students are more likely to become more self-confident and independent learners with the support of these devices, therefore, the learners' academic success in the long run.

While the introduction of education technologies has significantly assisted the learning experience of children with Down's Syndrome and expanded their opportunities, they continued to face challenges throughout the learning process, and researchers have continued examining ways to improve their experience. The majority of research in this area has concentrated on specific technologies and enactment strategies, including the provision of Attention and Stochastic Gradient Descent for Augmentative and Alternative Communication. as well as game-based learning environments [2]. Unfortunately, these studies typically focus on a single technology or technique without providing systematic insights about overall trends, or which tools might be successfully combined with other tools.

To fill this gap, this paper provides a systematic overview of current educational technologies for children with DS by investigating research trends and proposing effective combinations of existing interventions. It also examines these technologies' impact on relational support, particularly how teachers or caregivers could use these technologies to improve educational performance [3], revealing to what extent human capital facilitates the effective implementation of educational interventions.

Ultimately, this review asks: What are the trends and patterns in educational research on the use of educational technologies among children and adolescents with DS?

2. Theoretical framework

This paper draws on Lev Vygotsky's Sociocultural Theory of Learning, the idea that human cognitive functions first emerge on a social level and are then internalized by individuals [4]. To achieve cognitive growth, individuals require relational learning support within their social context. Vygotsky's core assertion is that children learn intellectually and adaptively significant methods of thinking and behaving by interacting with key individuals in their environment, such as their parents and teachers [4]. Relatedly, this theory proposes the concept of the zone of proximal development (ZPD), defined as the difference between the learner's capacity to carry out a task individually versus with assistance [4]. Vygotsky refers to the interaction between the two parties as scaffolding, in which assistance is provided by the more knowledgeable other (MKO), either a parent, teacher, or peer [5].

Several studies over the past twenty years have used Vygotsky's theory to examine the social and cognitive development of children with disabilities, particularly their learning processes and educational needs. For example, Smith et al., explored the role that technology can play as an intermediary tool in the education of children with autism spectrum disorder [6]. Their findings show that while interactive digital tools may not directly correlate with speech development, they can serve as an effective cultural scaffolding mechanism, helping children with autism participate in various activities where they can develop social and communication skills. The study concludes that cultural tools such as technology can regulate children's cognitive development [6].

The Sociocultural Theory of Learning suggests that therapists, teachers, parents, and caregivers play indispensable roles for children with DS. They provide a scaffold to these learners as they traverse zones of proximal development, allowing children with DS to perform more complex activities with greater competence than they could accomplish unassisted [7]. In other words, this framework would predict that the appropriate application of educational technologies matched with strong relational support would maximize learning outcomes compared to technologies without this support, which in turn, would highlight the importance of holistic approaches to technologies.

3. Method

Our approach was to conduct a systematic literature review. We accumulated comprehensive data from a literature search in an EBSCO database using an end-notes index/questionnaire since titles, abstracts, and full articles. We aimed to capture a wide range of studies in this search by using keywords and subject headings as outlined in Table 1. The search terms in the table were connected using the Boolean expression "OR." Between different categories, a concept-linking operator – "AND" was employed. The search period included publications up to July 16, 2024, comprising both recently published studies and historical ones. The search strategy identified 132 studies containing the relevant keywords to import for screening. Covidence, the systematic review production tool then identified and eliminated nine duplicates. Afterwards, we filtered out articles from the remaining 123 studies based on the following criteria:

1. Studies must focus on the use of educational technologies for children and adolescents with DS.
2. Studies published in the last 5-10 years were prioritized to identify current trends.
3. Studies must provide insights into patterns, best practices, challenges, and outcomes of using educational technologies in this population.
4. Studies must be written in Chinese or English.

Table 1: Examples of search terms used in EBSCO database

Search Term Category (Joined with AND)	Search Terms in Abstract (Joined with OR)
Down Syndrome	"Down Syndrome*" OR 'Downs Syndrome*" OR "Down's Syndrome*"
Educational Technology	"Educational technolog*" OR "E-learning technolog*" OR "Learning management system*" OR "LMS" OR "Digital learn*" OR "Edtech*" OR "Ed tech*" OR "educational app*" OR "education app*" OR "learning app*" OR "mobile learn*" OR "mlearn*" OR "learning tech*" OR "Online cours*" OR "Distance education*" OR "Distance learn*" OR "Educational softwar*" OR "education softwar*" OR "classroom tech*" OR "learning tech*" OR "virtual learn*" OR "adaptive learn*" OR "technology supported ed*" OR "technology supported learn*" OR "distance ed*" OR "online cours*" OR "virtual cours*" OR "virtual learn*" "STEM education app*" OR "Cloud-based education*"

As shown in Figure 1, we excluded 73 studies during the screening process. Next, the full texts of the remaining 50 studies, including their main ideas and research directions, were retrieved from EBSCO and re-screened based on the evaluation criteria. We excluded another 19 unrelated studies,

of which 11 had flawed designs, 4 had inappropriate settings, and 3 had issues with the route of administration as an outcome. Ultimately, 31 studies were used for our analysis.

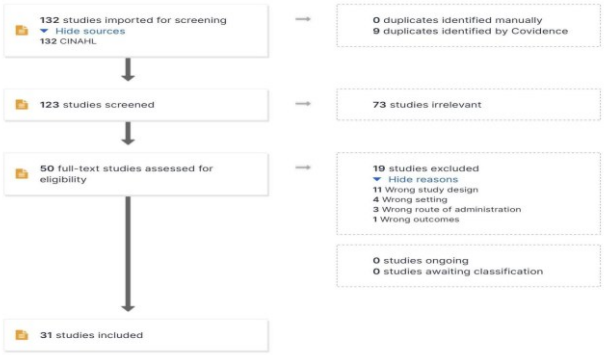

Figure 1: PRISMA diagram of the identification process through Covidence

Our extraction scheme took direction from Vygotsky's Sociocultural Theory of Learning. Initially, we distinguished studies from each other based on whether they presented an optimistic or pessimistic view of science and technology. Next, we further categorized studies by whether they focused on technological interventions alone or on technological interventions with relational work. With these distinctions in place, we analyzed these studies for differences in outcomes when applying various technologies to educate children with DS.

Such a rigorous process of weighting and transforming the results of each study is necessary to have a complete and accurate analysis of studies included in our review of educational technologies for children with Down's syndrome. In our approach, the quality of each study was first gauged since methodological rigor, sample size, and experimental design. Quality assessment for each study design was performed against standardized quality assessment tools, including checklists from the Joanna Briggs Institute and CONSORT guidelines. More robust methodologies, like RCTs and longitudinal designs, were given more weight, as they generally are more reliable sources of evidence. In most cases, such studies offered better internal validity and more reliable results; therefore, they were of higher value to our analysis. On the other side, studies that are poorly designed, for instance, cross-sectional survey or small sample size, were weighted lightly since these studies have weaker control on confounding variables and ensure less generalizability.

Next, we looked at the experimental design of each study. Here, what mattered was the degree to which it allowed for an isolated test of educational technologies from other factors. We were particularly interested in studies that had comparison or control groups and measurement instruments with good validity to isolate more clearly the specific effects of the technology on learning. Studies that provided clear and measurable outcomes—like improvements in communication or cognitive development skills, for example—were weighted more heavily. This helped to ensure that the analysis focused on studies providing rigorous and relevant evidence on the impacts of the educational technologies being reviewed.

Another very important factor in our weighting process is relevance. We checked whether the technology and the interventions in each study were appropriate for children with Down's Syndrome and whether the study addressed some key issues relevant to their educational needs. Studies that investigated a range of technologies or explored the effectiveness of technology combined with relational support, such as teacher or caregiver involvement, were judged to be more relevant and thus assigned higher weights. Where such was possible, results were converted to a common metric to synthesize the data. This involved standardization of effect sizes like Cohen's d or odd ratios so that they would be comparable in studies. In the case of studies reporting results in various formats

or metrics, we converted the findings into comparable measures. In this way, we could aggregate data effectively and conduct a meta-analysis to look at the overall impact of educational technologies. Such aggregation of data from these weighted and transformed results identified some interesting trends. Comparisons between educational technologies with relational support had larger positive effects compared to studies focused solely on technology. This would suggest that integration of human capital has a maximizing effect on the effectiveness of educational technologies. Furthermore, in high-quality studies, stronger effects came through when relational support was involved, thus further confirming how technology ought to go hand in hand with effective human interaction. In assessment and transformation, our analysis gave an exact clear picture with a substantiation of how educational technologies, if paired with relational support, can positively impact the learning experiences of children with Down's syndrome.

4. Results

To examine what present-day research reveals about technological interventions to educate children with DS, we conducted a systematic review of the existing literature. Our analysis divided the literature into two categories: research that studied technologies used by participants alone and technologies used by participants in combination with relational work with another human. Of the studies that we surveyed, over 85% were relational. In addition, all works expressed optimism for the use of these interventions. The paragraphs below outline our main conclusions.

First, we can infer that assistance provided by parents and teachers is essential to increase the impact of these technologies. In the study of an emergency remote parent training program during COVID-19, parent involvement seems to be the factor that determines the intervention's success. Parents varied in how prepared they were to help their children in terms of access, engagement, and the completion of their assignments [8]. Given that children with DS need more assistance and motivation, researchers find it essential that parents understand their role in developing their children's skills. At the same time, a study of using videos to train teacher paraprofessionals on pivotal response techniques for children with DS by Smith et al., shows that teachers' content knowledge of how to utilize pivotal response are important in the remote program's educational efficacy [8]. Teachers trained in these skills can assist students with a wide array of abilities, which will prevent potential long-term consequences due to children falling behind [9]. The provision of instructional videos that help teachers combine technology and pedagogy allow them to provide additional relational support, which makes technology a much more natural entity than an artificial tool for learning [10].

Findings from the systematic literature review suggest that while technology can give us insights into individual and relational features of learning and their effect on educational outcomes, the relational aspects of the educational technologies themselves have been largely unexplored. Further research is necessary since even though the surveyed technologies are primarily aimed at supporting the tutor, the relationship that the parents and tutors form during their interactions throughout the learning process is also vital. That said, it is clear from the included studies that using such systems offers students a functional learning environment with scaffolding and opportunities to provide regular feedback and evaluation. This is a core relational benefit of learning that makes the given technology have value. Accordingly, in the 31 literature we selected, most of them held and optimistic view of technology while emphasizing that communication and cooperation between people is a continual challenge in educating those with DS.

5. Conclusion

This review of educational technologies for children and adolescents with DS hopes to make a significant contribution to ongoing scholarly conversations. However, the absence of substantial analysis of how relational scaffolding impacts technological interventions underscores the limitations of the evidence in support of educational technologies. Most prior research focuses on technology itself, rather than understanding the relationship between the educational technology and the interactions between children with DS and parents, teachers, and caregivers. Further research must investigate the outcomes of educating children with Down's Syndrome using different learning theories to obtain evidence that technology systems combined with relationship-based interventions can increase learning.

We believe this research will help expand the current research's epistemological landscape and encourage others toward systemic analyses of remedial measures on investigations that fill research gaps. Future work should expand research into both individual and combined efficiencies of these educational technologies and the way these tools can be optimized when people who use them are also part of the support themselves. This could facilitate the monitoring and evaluation of how different pedagogical practices in technology use and the nature of relational interactions altogether influence these technology-based interventions. This process could further probe into how technology works in conjunction with and augments the educative efforts in children with DS.

Evaluating longitudinal and diverse educational settings will create the best practice approach, from both technological and relational points of view, where each element can be differently mixed to better fit the unique needs of this population. Research should investigate how kinds of relational support—say, from family and friends or teachers or peers—used with what forms of educational technology may help. It is also fundamental to recognize whether time and culture seem to interact with the curriculum to influence learning outcomes and if so, in what ways. Only through such thorough evaluations can more targeted and adaptable strategies of education be developed.

Ultimately, what needs to happen is a more holistic approach that can bring the technological developments and relational dynamics into perspective for the creation of more effective, contextually relevant educational strategies. This will, from henceforth, be more helpful to such children who are Down's baby, as it ensures that technological tools not just work with but work inside relational reference frames to get maximum educational benefits.

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Yanchun Du and Boxing Zhang contributed equally to this work and should be considered co-first authors.

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