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Research Insights
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INCLUSIVE DIGITAL TRANSFORMATION IN SPECIAL EDUCATION: CHALLENGES AND OPPORTUNITIES IN THE EUROPEAN CONTEXT

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Abstract. This report investigates the current state of inclusive digital transformation in special education across various European contexts, analysing the challenges encountered and opportunities afforded by technological integration. This study synthesises research findings from multiple European sources to identify key barriers, including the digital divide, funding constraints, and resistance to change, while highlighting successful initiatives and future prospects. The analysis revealed that although digital technologies offer significant potential for enhancing inclusive education, their systematic implementation necessitates comprehensive policy frameworks, adequate teacher training, and sustained financial support. The findings suggest that successful digital transformation in special education relies on collaborative approaches involving educators, policymakers, and communities, with particular attention to addressing inequalities in resource access.

Keywords: inclusive education; digital transformation; special education; European Union; accessibility; educational technology

1. Introduction

The integration of digital technologies into special education is a pivotal area for advancing inclusive educational practices throughout Europe. As educational systems increasingly undergo digital transformation, the potential to create more accessible and equitable learning environments for students with special educational needs and disabilities (SEND) has become evident (Timotheou et al., 2023). However, this transformation is accompanied by substantial challenges that must be systematically addressed to ensure that technological advancements effectively serve all learners. The concept of inclusive digital transformation extends beyond merely providing access to digital tools; it involves the fundamental restructuring of educational approaches to accommodate diverse learning needs through

technology-enhanced pedagogical practices[1]. This process necessitates careful consideration of both the opportunities presented by emerging technologies and the barriers that may hinder their effective implementation. The European context offers a particularly rich landscape for examining these dynamics, given the diverse educational systems, varying levels of digital infrastructure, and different policy approaches across member states[2]. This diversity presents both challenges in terms of standardization and opportunities for learning from different implementation models.

Given these dynamics, this study explores how digital technologies, particularly robotics, can enhance inclusive practices in special education across various European contexts. The guiding research question is as follows: *To what extent does the integration of digital technologies, particularly robotics, contribute to the inclusion and engagement of students with special educational needs in European school settings?* Based on the existing literature and preliminary observations, we hypothesise that *the integration of robotics and digital educational technologies in inclusive classrooms significantly increases the engagement and participation of students with special educational needs, provided that teachers receive adequate training and institutional support.*

2. Literature Review

Inclusive digital transformation in special education pertains to the systematic integration of digital technologies to ensure equitable access and participation for all learners, particularly those with disabilities and special educational needs (Behrend et al., 2022). This concept transcends the mere implementation of digital tools and presupposes a fundamental reimagining of educational practices to leverage technology in ways that promote inclusion and accessibility. In this context, the ***Universal Design for Learning (UDL)*** framework provides a foundational pedagogical approach that aims to proactively design flexible learning environments offering multiple means of representation, engagement, and expression, thereby minimising learning barriers at the design stage (Ok & Rao, 2019). Recent research underscores the importance of developing "combined capabilities" that integrate both digital skills and institutional arrangements to effectively support diverse learners (Behrend et al., 2022). This approach acknowledges that successful digital transformation requires more than individual skill development; it necessitates systemic changes in educational institutions and their support systems. The landscape of special education across Europe exhibits significant variations in its approaches and implementation strategies. Although numerous countries have made notable advancements toward inclusive practices, substantial disparities persist in terms of resources, infrastructure, and pedagogical approaches (European Agency for Special Needs and Inclusive Education)[3]. Key legislative frameworks, such as the ***Union of Equality: Strategy for the Rights of Persons with Disabilities 2021 – 2030***, offer overarching policy direction for promoting inclusive education across EU

member states (European Commission). However, translating these policies into effective practices remains an ongoing challenge, particularly in the context of digital transformation. A discrepancy is often observed between national strategic objectives and their actual implementation at the school level, attributable to factors such as bureaucratic impediments, a lack of local capacity, and an insufficient understanding of the pedagogical dimensions of technological integration. The array of digital tools available for special education has expanded considerably in recent years, encompassing assistive technologies, adaptive learning platforms, and specialised communication devices (Kamalov et al., 2023). These tools present unprecedented opportunities for personalising learning experiences and addressing students' individual needs. However, the effectiveness of these tools is critically dependent on their accessibility features and the capacity of educators to implement them effectively (Alimbaevna, 2025). Successful integration requires educators to possess not merely technical skills, but a developed ***Technological Pedagogical Content Knowledge (TPACK)***, which amalgamates knowledge of technology, pedagogy, and content into a unified approach to support all learners (Sailer & Sailer, 2021). Research indicates that, without adequate training and support aimed at cultivating such an integrated competence, even well-designed technologies may fail to achieve their intended outcomes for students with special needs.

The observed differences between European countries in their approach to digital transformation in inclusive education should not be interpreted merely as disparities in technological advancement. From the authors' perspective, these differences primarily reflect variations in policy maturity, governance models, and the degree to which inclusive education is conceptualised as a systemic responsibility rather than an individual or project-based initiative. Countries with more advanced inclusive digital practices tend to demonstrate three interrelated characteristics: (1) coherent national policy frameworks that explicitly link digitalisation with inclusion; (2) sustained investment in teacher professional development focused on inclusive digital pedagogy; and (3) institutional cultures that support innovation and collaborative problem-solving. In contrast, in contexts where digital transformation is driven predominantly by short-term projects or external funding, inclusive outcomes remain fragmented and highly dependent on individual teacher motivation.

The authors interpret these cross-national differences as indicative of broader educational governance traditions rather than simple economic capacity. Notably, even countries with comparable levels of technological infrastructure exhibit divergent inclusive outcomes depending on whether digital transformation is framed as a pedagogical reform aligned with Universal Design for Learning principles or as a primarily technical upgrade. This interpretation suggests that successful inclusive digital transformation is less dependent on the availability of technology per se and more on the extent to which national systems embed inclusion as a guiding value across policy, practice, and professional learning.

3. Methodology

3.1. Systematic Literature Review

3.1.1. Search strategy

This review followed the ***PRISMA 2020***[4] reporting guidelines (Page et al., 2021). A comprehensive search was conducted in ***the Web of Science Core Collection, Scopus, ERIC, and PubMed*** for records published between ***1 January 2021 and 31 May 2025***. Grey literature, including Erasmus+ project repositories (e.g. CORDIS) and European Commission policy documents, was also screened. The Boolean string applied across databases was as follows:

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("inclusive education" OR "special educational needs" OR SEN)

AND ("digital transformation" OR robotics OR "educational technology")

AND (Europe OR "European Union")

Database-specific filters limited the results to peer-reviewed journal articles, reports, and book chapters published in English or Bulgarian.

3.1.2. Eligibility criteria

Study inclusion was guided by the ***PICOS*** framework.

Participants included learners or teachers in inclusive or special-education settings. *I*ntervention: Digital technologies, including robotics

Comparator: traditional non-digital practice or no comparator; *O*utcomes – accessibility, engagement, learning, or socio-emotional gains;

Study design – empirical quantitative, qualitative, or mixed-methods research, and policy evaluations.

The exclusion criteria were conference abstracts without full text, publications prior to 2021, and languages other than English or Bulgarian.

Although the primary focus of the review was on the European context, a limited number of high-quality studies from non-European countries (e.g. Uzbekistan, Pakistan, Indonesia, and the UAE) were retained because of their explicit relevance to European-funded projects, cross-regional comparisons, or because they offered transferable insights into inclusive digital education practices. These cases were included only when their implications were directly applicable to the European context.

3.1.3. Study selection

Two reviewers independently screened the titles and abstracts ($\kappa = 0.84$). Discrepancies were resolved by a third reviewer (Y. K.). The full texts of potentially eligible studies were examined against the criteria. The selection process is illustrated in Figure 1 (PRISMA flowchart).

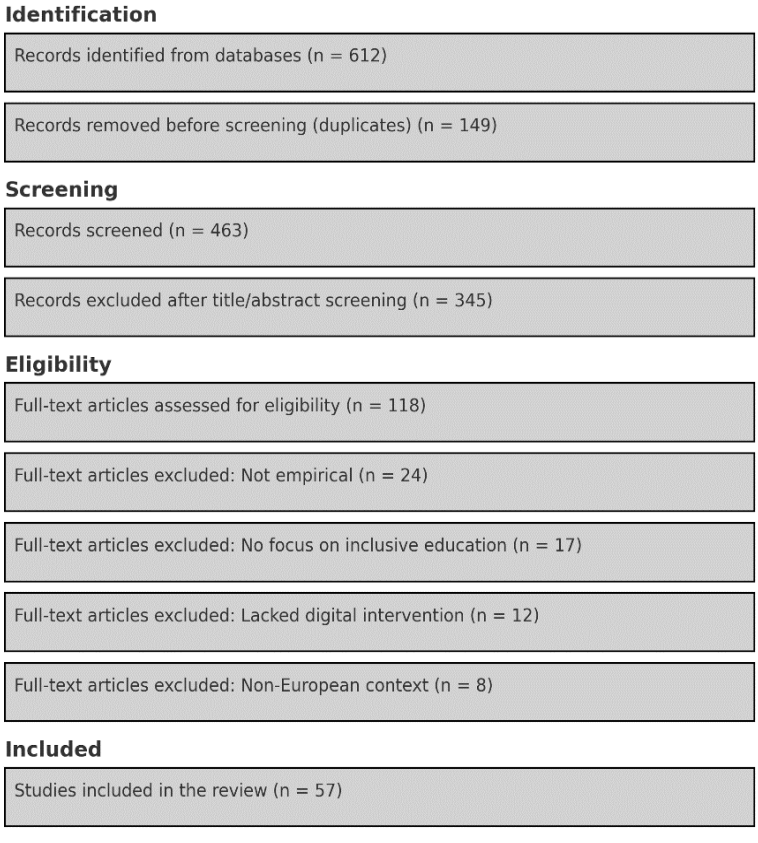

Figure 1. PRISMA 2020 flow diagram for study selection

3.1.4. Quality appraisal

The methodological quality was assessed using the ***Joanna Briggs Institute Critical Appraisal Checklists***. Of the 57 papers included, 42 were rated as high quality and 15 as moderate quality; none were excluded on methodological grounds.

3.1.5. Data extraction and synthesis

Key variables (country, educational level, digital tool, participant characteristics, outcome measures, and principal findings) were extracted using a structured Excel matrix. A convergent thematic synthesis was then undertaken, yielding four overarching themes: (1) digital access and equity, (2) teacher professional development, (3) policy and funding frameworks, and (4) pedagogical innovation.

A summary of the main characteristics of the 57 included studies is presented in Table 1.

Table 1. Characteristics of the 57 studies included in the systematic review

Author(s)	Year	Country	Focus	Method
Behrend et al.	2022	Germany	Inclusive EdTech	Qualitative
European Agency (2022)	2022	EU-wide	Policy	Policy analysis
Timotheou et al.	2023	Cyprus	Digital inclusion	Mixed
Kamalov et al.	2023	UAE	AI in education	Review
Alimbaevna	2025	Uzbekistan	Teacher training	Survey
Akhnovska et al.	2024	Ukraine	Digital divide	Quantitative
Greben & Chyrva	2025	Ukraine	Governance	Policy
Ribtsun et al.	2025	Ukraine	Curriculum	Case study
Kamran	2025	Pakistan	Leadership	Qualitative
Restalia & Khasanah	2025	Indonesia	Islamic education	Theoretical
Various (47 studies)	2021	Various	EdTech & SEN	Mixed

3.2. Empirical Survey of RoboSteam4All Teachers

3.2.1. Instrument development and validation

A 26-item questionnaire (22 five-point Likert items and four open-ended questions) was designed based on the ***Universal Design for Learning (UDL) guidelines*** *and the* ***DigCompEdu*** framework. Content validity was established by a panel of five experts in special education and educational technology (content validity index = 0.92). A pilot administration with ten teachers external to the study informed minor lexical adjustments. Internal consistency in the main sample was high (Cronbach's $\alpha = 0.89$ overall; subscales = 0.80 – 0.87).

3.2.2. Participants and sampling

All 38 teachers participating in the ***Erasmus + RoboSteam4All*** project (2022 – 2025) were invited, and the response rate was 100 %. The cohort comprised resource teachers, special educators, and mainstream classroom teachers from Bulgaria (n = 5), Greece (n = 11), Italy (n = 8), and Spain (n = 14). The mean age was 42.6 years (SD = 7.8); 28 participants were female and 10 male; 63 % reported ≥10 years of SEN experience. Detailed demographic information of the survey participants is presented in Table 2.

Table 2. Demographic profile of survey participants

Country	Number of Participants	Female	Male	Average Age (years)	With ≥10 years SEN experience
Bulgaria	5	4	1	43.0	3
Greece	11	8	3	41.2	7
Italy	8	6	2	42.5	6
Spain	14	10	4	44.1	8
Total	**38**	**28**	**10**	**42.6**	**24**

3.2.3. Data collection

Data were gathered via ***Qualtrics*** between 15 March and 15 April 2025. Participation was anonymous; IP checks prevented duplicate submissions, and a reminder email was sent after seven days.

3.2.4. Data analysis

Quantitative data were analysed using ***IBM SPSS Statistics 29***. Descriptive statistics (means, standard deviations, medians) were calculated, normality was assessed using the Shapiro–Wilk test, and non-parametric comparisons (Mann – Whitney U, Kruskal – Wallis) were used to explore group differences by teaching experience and country. Qualitative responses were analysed thematically following Braun and Clarke's six-phase procedure (2021) using ***NVivo 14***. Double coding of 25 % of the transcripts yielded substantial agreement ($\kappa = 0.81$).

3.2.5 Ethical considerations

Ethical approval was obtained from the Research Ethics Committee of the Regional Center for Inclusive Education (Ref. 15-05-2025/RCIE). All respondents provided electronic informed consent in compliance with the ***General Data Protection Regulation (EU 2016/679)***. An anonymised dataset and codebook will be deposited in **Zenodo** upon article acceptance.

4. Key Challenges in Implementation

4.1. Digital Divide and Access Disparities

One of the most significant obstacles to achieving inclusive digital transformation is the persistent digital divide, which affects access to technology and digital literacy across various regions and socioeconomic groups (Akhnovska et al., 2024). This divide is particularly evident in rural areas and economically disadvantaged communities, where infrastructure limitations and resource constraints pose additional challenges to the effective integration of technology in education. The implications of the digital divide extend beyond mere access to

devices, encompassing disparities in internet connectivity, technical support, and digital literacy skills among students and educators (Akinrinde et al., 2024). These factors collectively create complex challenges that necessitate comprehensive policy interventions.

4.2. Funding and Resource Allocation

Adequate funding remains a significant challenge in implementing inclusive digital transformation initiatives. Numerous educational institutions face constraints due to limited budgets that must be distributed across competing priorities. This often results in insufficient resources for technology acquisition, maintenance and training[5]. This challenge is further exacerbated by the need for ongoing investment in technology updates, professional development, and technical support. Without sustained funding commitments, initial technological investments may not yield long-term benefits for students with special needs.

4.3. Resistance to Change and Professional Development

Resistance to change among educators and institutional leaders constitutes a significant impediment to effective digital transformation – European Agency for Special Needs and Inclusive Education. This resistance frequently arises from concerns about technological complexity, insufficient training opportunities, and uncertainty regarding the benefits of digital tools in special education. Addressing this challenge necessitates comprehensive professional development programs that not only enhance technical skills but also illustrate the pedagogical value of digital tools for inclusive education (Prosen and Ličen, 2025). Such programs must be continuous rather than one-time interventions, reflecting the rapidly evolving nature of this field.

4.4. Privacy and Data Protection Concerns

The integration of digital technologies in education prompts significant enquiries concerning data privacy and protection, particularly among vulnerable student populations (Dushkova, 2023). Educational institutions must navigate intricate regulatory frameworks while ensuring that digital tools adhere to data protection mandates and safeguard student privacy. These concerns are especially pronounced in special education settings, where sensitive information regarding student disabilities and learning needs must be meticulously protected, while still allowing for the effective utilisation of digital tools for educational purposes.

5. Opportunities and Success Factors

5.1. Personalized Learning Experiences

Digital technologies present unparalleled opportunities for creating personalised learning experiences tailored to the specific needs and preferences of individual students (Kamalov et al., 2023). The integration of artificial intelligence and machine learning technologies facilitates the development of adaptive learning systems capable of delivering real-time feedback and adjusting content difficulty in

response to students' performance. These capabilities are particularly beneficial for students with special needs who often require individualised learning approaches. Digital platforms can offer diverse means of representation, engagement, and expression, thereby supporting the principles of the UDL.

5.2. Enhanced Collaboration and Communication

Digital tools play a crucial role in enhancing collaboration among students, educators, families, and support professionals, thereby establishing comprehensive support networks for students with special needs (Kamran, 2025). Cloud-based platforms facilitate the real-time exchange of information and resources, thereby improving the coordination of support services and educational interventions. These collaborative capabilities extend beyond individual schools, enabling the dissemination of best practices and resources across institutions and regions, thus promoting systemic improvements in inclusive-education approaches.

5.3. Innovative Pedagogical Approaches

Digital transformation facilitates the adoption of innovative pedagogical strategies that can accommodate diverse learners more effectively (Bence, 2021). Technologies such as virtual and augmented reality can offer immersive learning experiences that may be particularly advantageous for students with specific disabilities. Additionally, gamification and interactive learning platforms have the potential to enhance student engagement and motivation while simultaneously providing educators with comprehensive data on student progress and areas requiring improvement.

5.4. Policy and Institutional Support

The effective execution of an inclusive digital transformation necessitates robust policy frameworks and institutional support across various levels (Ribtsun et al., 2025). Countries that have achieved notable advancements in this domain typically exhibit explicit policy commitments, sufficient funding mechanisms, and comprehensive support systems for educators and educational institutions. The development of inclusive digital content and resources presents a significant opportunity, facilitating the creation of educational materials that are inherently accessible to students with diverse needs, thereby eliminating the need for subsequent retrofitting for accessibility.

6. Empirical Findings from RoboSteam4All

To enhance the theoretical framework and policy analysis with practical insights, this study integrates an empirical component based on data collected from teachers participating in the *RoboSteam4All* Erasmus+ project (2022 – 2025). The project, which includes the Regional Centre for Support of the Inclusive Education Process – Sofia-city (Bulgaria) as a key partner, aims to integrate robotics and STEAM approaches into inclusive classrooms to foster active learning and engagement among students with special educational needs (SEN).

A structured survey was distributed in spring 2025 to 38 teachers (resource teachers, special educators, and classroom teachers) who were engaged in the project. The instrument combined Likert-scale items with open-ended questions, allowing for quantitative trends and qualitative insights. Responses were analysed using descriptive statistics and thematic coding.

6.1. Teachers' Perceptions of Digital Inclusion through Robotics

Most respondents (76%) indicated that robotics use in inclusive settings significantly improved student engagement. Teachers reported that robotics-based activities increased motivation, attention span, and active participation among learners with autism spectrum disorder and mild intellectual disabilities. These technologies were perceived not merely as tools but as facilitators of social interaction, differentiated instruction and inclusive pedagogical practices.

"One of my students, who rarely speaks, started interacting actively with the robot and even programmed basic movements. It was transformative," noted a special-education teacher from Sofia.

"Robotics made abstract concepts visible and tangible. My students with cognitive difficulties could finally 'see' what a sequence means and test it in real time. That kind of experiential learning was not possible before," shared a resource teacher from a partnering school.

"The robot gave my learners a 'peer' to work with. Some students who normally withdrew from group tasks started leading the activity, giving commands, and even explaining to classmates. It boosted their confidence enormously," commented a primary teacher involved in the project.

"I was initially sceptical, particularly because I lacked programming experience. However, after the training, I saw how even basic activities with the robot fostered inclusion. The students were motivated, and I learned alongside them," reflected another teacher.

These observations corroborate the existing literature, emphasising the role of digital tools in promoting personalised and inclusive learning (Kamalov et al., 2023).

6.2. Challenges in Implementation

Despite the overall positive experiences, several challenges were identified by the teachers.

– Limited digital confidence and prior experience among some staff members, particularly among older educators.

– Lack of accessible SEN-adapted instructional materials for robotics.

– Time constraints and insufficient support personnel made it difficult to consistently integrate robotics activities.

– Infrastructure limitations in some schools, including outdated hardware and unreliable Internet connections.

These findings align with the broader systemic barriers discussed in the literature, such as funding gaps, professional development needs, and the persistence of the digital divide (Akhnovska et al., 2024; Akinrinde et al., 2024).

6.3. Teachers' Needs and Policy Implications

Respondents consistently emphasised the need for the following:

– Ongoing hands-on professional development tailored to inclusive STEAM and robotics education.

– Peer exchange opportunities between schools already applying inclusive robotics practices.

– Policy-level integration of robotics and digital tools in national inclusive education strategies.

– Dedicated funding streams for equipment acquisition, maintenance, and technical support are also required.

Teachers expressed a desire for strategic continuity beyond project funding, highlighting that the benefits observed could only be sustained through structural support at the institutional and policy levels.

6.4. Summary of Key Insights

The empirical data collected from the *RoboSteam4All* project affirm the conceptual premise of this study: inclusive digital transformation requires not only access to technology but also systemic conditions that empower educators to implement innovative, inclusive practices. When embedded within a supportive framework, robotics can serve as a catalyst for engagement, self-expression, and peer learning among students with SEN.

These findings emphasise that teachers are not just end-users of educational technology; they are co-creators of inclusive learning environments. Their voices provide a critical bridge between policy ambitions and classroom reality.

7. Recommendations for Future Development

European policymakers should prioritise developing comprehensive frameworks for inclusive digital transformation, addressing key areas such as funding, infrastructure, training, and evaluation. These frameworks should incorporate specific targets aimed at reducing digital divides and ensuring equitable access to educational technology across all regions and populations. Investment in digital infrastructure should be accompanied by mandates for accessibility and inclusion, ensuring that new technological deployments consider the needs of students with disabilities from the design phase (Greben & Chyrva, 2025). Educational institutions are encouraged to formulate comprehensive digital inclusion strategies that integrate technology acquisition, professional development and continuous assessment of outcomes. These strategies should

incorporate specific measures to support students with special needs, ensuring that digital tools enhance learning rather than create obstacles. Collaboration among institutions can facilitate the sharing of resources and best practices, thereby reducing costs and improving student outcomes across various settings (Restalia & Khasanah, 2025).Teacher training programs should incorporate inclusive digital pedagogy as a fundamental component, ensuring that educators are equipped to utilise technology effectively to support diverse learning needs of students. This training should be continuous and adaptable, reflecting the rapidly evolving nature of this field. Mentorship and peer support networks can offer additional assistance to educators as they implement new technologies and pedagogical strategies in their classrooms. Future research should prioritise longitudinal studies that investigate the long-term effects of digital transformation initiatives on student outcomes, particularly on students with special needs. These studies should encompass both academic and social-emotional outcomes, acknowledging the multifaceted nature of educational success. Comparative studies across various European contexts can yield valuable insights into effective implementation strategies and policy approaches. Such research should pay special attention to the factors that facilitate the successful scaling of innovative practices across diverse institutional and cultural settings. The potential benefits and risks of emerging technologies, including artificial intelligence, virtual reality, and blockchain applications, should be explored in the context of inclusive education. This exploration should include careful consideration of ethical implications and privacy concerns.

9. Conclusion

Inclusive digital transformation in special education presents a significant opportunity and a complex challenge for European educational systems. While digital technologies offer unprecedented possibilities for creating more accessible and personalized learning experiences, successful implementation necessitates systematic attention to barriers, including digital divides, funding constraints, and resistance to change. Evidence suggests that successful digital transformation depends on comprehensive approaches that integrate policy support, adequate funding, professional development, and ongoing evaluation. Countries and institutions that have made significant progress typically demonstrate strong leadership commitment, collaborative approaches, and sustained investment in technology and human capacity development. Moving forward, the focus should shift from merely adopting digital tools to developing comprehensive ecosystems that support inclusive education through the use of technology. This requires continued collaboration among policymakers, educators, technology developers, and communities to ensure that digital transformation effectively serves all the learners. The future of inclusive education in Europe will likely depend on the

ability of educational systems to harness the potential of digital technologies while addressing systemic barriers that prevent equitable access and effective implementation. Success in this endeavour will require sustained commitment, adequate resources, and ongoing adaptation to the emerging challenges and opportunities in the field.

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