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This working paper has been authorised by Andreas Schleicher, Director of the Directorate for Education and Skills, OECD.

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Abstract

This review examines the current literature on the use of digital technologies to support young children with special needs in early childhood education and care (ECEC). It identifies four key areas of focus, which relate to understanding and articulating the purpose and focus for integrating assistive technologies (ATs) in ECEC; activating and integrating expertise in ECEC; developing an engaged community of experience and practice; and promoting and supporting quality AT design. Foundations for further developments are evident across the research literature and the review derives recommendations to provide direction for ECEC policy makers and staff, educational institutions and allied support networks for achieving the promise of AT for children with special needs in ECEC.

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Introduction

A child has special education needs if the child has a learning problem or disability that makes it more difficult to learn than most children of their age (nidirect government services, 2022[1]), with the World Health Organization classifying disability in terms of medical, social and biopsychosocial paradigms (WHO, 2007[2]). According to UNICEF (2022[3]), one in ten children worldwide have disabilities that may hinder their full and effective participation in society on an equitable basis. All children with special needs have the same rights as other children to education and care that caters for them academically, socially, emotionally, physically, and psychologically (Australian Government, 2022[4]; UN, 2022[5]; UNICEF, 2022[3]). To safeguard these rights, inclusive early childhood education and care (ECEC) policies are framed to consider the diversity of children and contexts to ensure all have equitable access to participation and high-quality services. Successful inclusive practices acknowledge the importance of additional assistance in breaking down barriers and supporting children with special needs to actively participate, engage and contribute to all aspects of their lives. Children with special needs may require additional support in opportunities for learning, communication, mobility, interpersonal interactions and relationship building. Educational experiences must be tailored, designed and implemented to meet their unique needs. This review investigates how digital assistive technologies (ATs), as resources in inclusive learning environments, may support young children with learning disabilities and special needs. All children require equitable access to high-quality learning and development opportunities so that they can develop and participate in society in the best ways possible.

The use of technology is an increasingly well-established strategy for supporting young children with special needs. An assistive technology device has been defined as “any item, piece of equipment or product system, whether acquired commercially off the shelf, modified or customised, that is used to increase, maintain, or improve functional capabilities of a child with a disability” (IDEA, 2004[6]). Digital technology engagement to support children with learning disabilities is becoming more common, particularly in the later years of education (Perelmutter, McGregor and Gordon, 2017[7]). In early ECEC settings, ATs are designed to support children to improve learning, behaviour, attention and communication (Parette and Stoner, 2008[8]). Assistive technology options have proliferated in recent years, due to the increase in software applications and innovative digital solutions designed to support individuals with special needs alongside increased access to digital technologies. In recent years, research has investigated the appropriation of mainstream technologies, such as digital games, to support children with special needs (e.g. Ringland et al. (2016[9])), as well as the ways in which greater accessibility can be effectively built into these technologies (Wobbrock et al., 2011[10]). As our review demonstrates, research on ATs in ECEC reports on outcomes in terms of academic learning, social skills and development, communication and behaviour change.

Inclusive education encompasses children with special needs attending general education classes for some or all their time. This inclusive approach is often referred to as mainstream education or mainstreaming. Inclusive education that caters for children with disabilities exerts additional demands on ECEC staff through the need to consider different instructional strategies and modify interactions with children, with additional professional development and training flagged as essential (OECD, 2021[11]). To support the special needs of young children and to engage with the diversity of children in a classroom, early childhood educators require an understanding of the philosophy and practices of inclusion, along with the associated required knowledge and skills, and sufficient resources of time and people, to implement development and learning-friendly practices in the classrooms (Parette and Stoner, 2008[8]). These requirements are obtained through additional resourcing and professional development. Professional development can support the preparedness of educators to use ATs to support young children with special needs. Inclusive classrooms also exert additional demands on peers and others in the classroom, so classroom peers require support in developing strategies and social understandings to support children with special needs. To enable the support of children with special educational needs, a solution can be found through an evidence-informed policy framework to achieve best practices in inclusive education.

This review examines the current literature on digital technologies to support the special needs of young children in ECEC and synthesises the findings with the aim of providing directions for policy and practice in ECEC. The review was conducted in accordance with the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses extension for Scoping Reviews (PRISMAScR, Tricco et al. (2018[12])) and is registered with the Open Science Framework (https://osf.io). More details on the methodology of the review are provided in Box 1.

Box 1. Methodology of the literature review

Eligibility Criteria. To be included in this review studies needed to have reported either quantitative or qualitative results of an evaluation of the use of ATs that targeted educational outcomes of pre-school children (aged 3-6 years) classed as having or at risk of having special needs. Studies were eligible for inclusion if published in English in peer-reviewed journals between 2018 and 2022. The search did not precede literature pre-2018 given the recent advancements in ATs. Studies were excluded if the technologies were tested in a laboratory or home context that did not mimic that of the educational context (i.e. a clinician or parent as interventionist rather than a teacher/educator), or if results for the targeted age group could not be differentiated from a mixed-age sample. Articles were also excluded if details of the technology used could not be extrapolated. Studies that were meta-analyses of extant literature, reviews, opinion pieces or book chapters were also excluded from the review.

Search Strategy. A systematic search was conducted in early 2022 of a range of databases to capture the interdisciplinary nature of ATs, as follows: APA PsycINFO; ERIC; ERC; Scopus; PubMed; MEDLINE; Web of Science; CINAHL. Developed and reviewed by the research team using the SPIDER framework (see Methley et al. (2014[13]) for a review), the following search terms were used to return a broad coverage of the transdisciplinary literature:

(disabilit* OR autism OR "autism spectrum disorder" OR ASD OR "attention-deficit hyperactivity disorder" OR "attention-deficit/hyperactivity disorder" OR "attention deficit hyperactivity disorder" ADHD OR dyslexia OR dyscalculia OR "special need*" OR "motor impairment*" OR "additional needs" OR "learning needs" OR "developmental delay") AND (Therap* OR Intervention*) AND (preschool*OR kindergarten* OR "early years" OR reception OR childcare OR daycare OR "early childhood education" OR "young children" OR "early childhood" or nurser*) AND ("Technology supported personalised learning" OR ”technology supported personalized learning" OR ”assistive technolog*" OR ”Technology enhanced learning" OR TEL OR "technology assisted learning" OR ”Computer-assisted learning" OR ”computer-aided learning" OR ”computer-aided instruction" OR robot* OR Edtech OR ”education technolog*" OR ”digital learning"). Limitations placed on the search included a date range of 2018-2022 published in English only.

Selection criteria and data extraction. As per the strategy and criteria above, 3 362 results were returned, including 525 duplicates, yielding a return of 2 837 articles, which, using Covidence, were title- and abstract-screened by two research assistants. A total of 1 957 articles were excluded and the remaining 880 were read in full by the same research assistants and any conflict of inclusion was reviewed by the whole research team and discussed to reach a unanimous decision. A final 52 articles were included for data extraction.

Data items were decided upon in via research team consultation with an activity theory perspective to consider actions, interactions and experiences (Verenikina, 2010[14]) and provide three key anchors on which to view ATs: the "what", "why", and "how" of assistive activities. Extracted were: characteristics of the article (author, year of publication, country where the research took place), context (e.g. mainstream pre-school, specialised pre-school), details and features of the technology used, who the technology was aimed at, outcome investigated, how the technology supported the execution of the outcome and key findings. Efficacy of results was not sought given the mixed-methods nature across the studies in the review, such that unified measures of effect size (e.g. Cohen's d) could not be obtained. The data extraction was performed by the two research assistants using Covidence, which involved a further review process, and a joint consensus established for each article.

Conceptual framework

An interactional approach has been employed in this review to understand the complex socially situated interactions that emerge when young children with special needs engage with assistive technology. Activity theory (Engeström, 1987[15]) provides a conceptual framework that allows careful consideration of the actions, interactions and experiences of children, carers and educators in their contexts. We draw on the basic premise of activity theory: human activity is a complex interaction between an individual and their surroundings (Verenikina, 2010[14]). The theory provides three key anchors on which to view ATs across the broad scope of the "what", "why" and "how" of an activity. The two-way mediation proposed by the theory suggests that the activity mediates and is mediated by several tools that encompass physical objects, ideas and language, and also the environment, culture, community and context (Hasan and Kazlauskas, 2014[16]). Any activity is influenced by social and cultural factors within the context in which the activity is taking place. Nardi (1996[17]) identified activity theory as a powerful and clarifying descriptive tool, offering the study of human-computer interaction a way to understand and describe the interacting elements of context, situation and practice. From an education perspective, activity theory has had many applications from understanding teacher approaches to information technologies (e.g. Karasavvidis (2009[18])), to analysing interactions with technology (e.g. Rozario, Ortlieb and Rennie (2016[19])) and to understanding intergenerational play (e.g. Siyahhan, Barab and Downton (2010[20])).

Complimentary to activity theory, the SETT (student, environment, tasks and tools) framework provides a structural mechanism for analysing and synthesising the reviewed literature. The SETT framework, which focuses on supporting student participation and achievement, is designed to guide informed decision making around ATs (Zabala, 2020[21]). It focuses on student needs and abilities; all aspects of the environment including materials, physical arrangement and support mechanisms; the tasks described in terms of activities and aligned with the curriculum; and the digital tools being employed. The framework allows for a multi-stakeholder approach to data analysis and reflects the "collective activity system" model (Engeström, 1987[15]) as the prime unit of analysis. This model assists in highlighting the complex interaction of the factors that influence the ways in which digital technologies can support the special needs of young children in ECEC. In addition, the framework includes an established set of criteria used in education to assist in the selection of ATs (Cochrane, 2012[22]). In this context, the SETT framework poses questions about the needs of the student, in their environment, the tasks that take place in that environment and the tools that children need to participate fully.

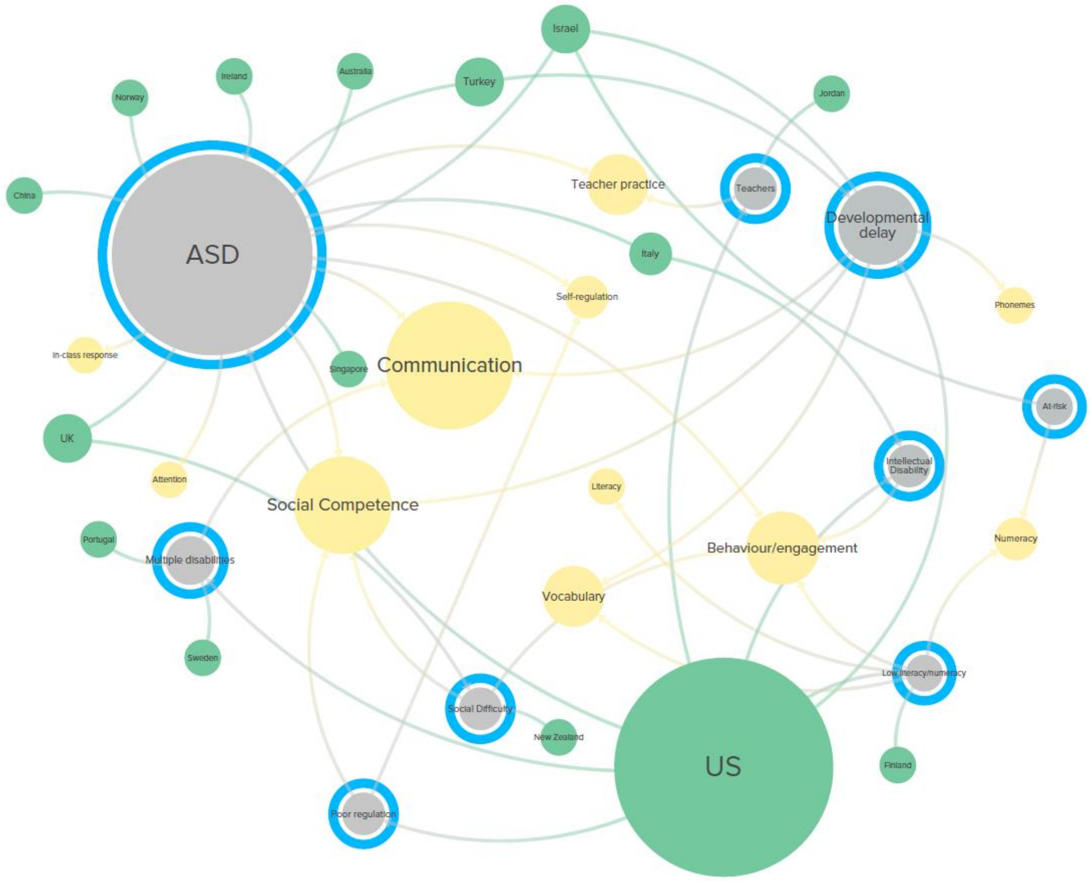
Findings

The findings from the review of the literature provide insights into the current landscape of assistive technology use and its impact on ECEC. First, the review identifies motivations for using ATs in early years education (referred to as ECEC) and outlines the focus for AT use in terms of who is being supported and what special needs are being addressed. The review then examines the settings in which ATs are deployed, identifying the key contextual features of research studies to understand the civic and environmental factors that influence interactions with AT. The final section details how AT is being used to support young children with special needs and discusses how the design, application and use of these technologies are leading to positive outcomes.

1. Motivations for using assistive technologies in ECEC

The section describes the primary objectives identified in the review of the literature for why ATs are used in ECEC. It outlines the intended outcomes in terms of learning, behaviour, equitable access, skill development and so on. Figure 1 illustrates the overall map of the interrelations between the target demographic (circled in blue), the focus outcome (yellow), and the global location in which the studies took place (green). The size of the elements signifies the frequency of studies belonging to that category such that the larger the circle, the more frequent in the data.

Figure 1. Summary of interrelationships across the research paper archive



Source: Authors' elaboration.

Of the final 52 articles, over half (n = 28) focused on children with autism spectrum disorder (ASD) (Bourque and Goldstein, 2020[23]; Cao et al., 2019[24]; Cardon, Wangsgard and Dobson, 2019[25]; Chapin et al., 2021[26]; Coogle et al., 2021[27]; Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]; Desideri et al., 2017[29]; Dueñas, Plavnick and Goldstein, 2021[30]; Eden and Oren, 2021[31]; Fuglerud and Solheim, 2018[32]) (Gevarter, Horan and Sigafoos, 2020[33]; Grygas Coogle, Floyd and Rahn, 2018[34]; Kemp et al., 2019[35]; Kouo, 2019[36]; Kossyvaki and Curran, 2020[37]; Lim, Ellis and Sonnenschein, 2022[38]; Lorah and Parnell, 2017[39]; Lorah, Miller and Griffen, 2021[40]; Meeks, 2017[41]; Muharib et al., 2019[42]) (O'Brien, Mc Tiernan and Holloway, 2018[43]; Pokorski et al., 2019[44]; Syrdal et al., 2020[45]; Thiemann-Bourque, McGuff and Goldstein, 2017[46]; Thompson and Johnston, 2017[47]; Tunc-Paftali and Tekin-Iftar, 2021[48]; Yong et al., 2021[49]), with a heavy focus on communication, social competence and behaviour/engagement. The prominence of AT research in young children with ASD is reflective of the capacity of technology to lend itself to support communication needs for these children through the use of video modelling, speech-generating devices, and using humanoid robots as social mediators, and the prevalence of diagnosis compared to other education-specific learning disorders that are undetectable during the pre-school years (for example, dyslexia, dyscalculia), meaning that effective early intervention for children with ASD is possible. Additional descriptions provided with research on ASD included expressive or alternative communication needs (Coogle et al., 2021[27]; Muharib et al., 2019[42]), moderate to severe (Bourque and Goldstein, 2020[23]; Kossyvaki and Curran, 2020[37]) or high functioning (Eden and Oren, 2021[31]), significant developmental delays (Meeks, 2017[41]) and a dual language learner (Lim, Ellis and Sonnenschein, 2022[38]).

More generalist developmental categories for disability were identified in 11 papers and included developmental disabilities (Boyle et al., 2021[50]; Oh-Young et al., 2018[51]; Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52]; Rivera et al., 2017[53]), school disability labels (D'Agostino, Douglas and Horton, 2020[54]), at risk of a developmental disorder (Dennis and Whalon, 2021[55]), cognition delays (Schebell et al., 2018[56]), global developmental disorder (Yong et al., 2021[49]); and developmental delays (Chai, 2017[57]; Encarnação et al., 2017[58]; Meeks, 2017[41]; Shamir, Segal-Drori and Goren, 2018[59]). Other focus areas for child participants included severe impairments without speaking ability (Borgestig et al., 2017[60]), cerebral palsy (Encarnação et al., 2017[58]), communication delays (Grygas Coogle, Floyd and Rahn, 2018[34]), brain injury (Encarnação et al., 2017[58]), mild hearing difficulties (Yong et al., 2021[49]), social and behavioural difficulties (Green et al., 2017[61]; Hall Pistorio, Brady and Morris, 2019[62]; Regan and Howe, 2017[63]), weak literacy and/or numeracy (Kong, Carta and Greenwood, 2021[64]; Schulz et al., 2020[65]), second language learners (Cassady, Smith and Thomas, 2018[66]; Fuglerud and Solheim, 2018[32]), and children with multiple disabilities (Chazin et al., 2018[67]). Two papers focused on children who were "at risk" for learning disabilities (Segal-Drori, Kalmanovich and Shamir, 2019[68]; Shamir, Segal-Drori and Goren, 2018[59]).

In terms of the intended outcomes for AT use in ECEC contexts, 11 different outcomes were identified, which can be loosely categorised into those that are education-specific and those that have a non-educational focus. Of the final articles in the review, 58% targeted general skill development (Table 1) rather than specific ECEC pedagogies and learning outcomes (Table 2). These general skills include communication, social competence, attention and self-regulation and are undeniably essential both for and beyond the education context. Over half of these articles focused on the use of AT to improve outcomes for children with ASD, while the remaining articles researched the impact of AT on children identified as experiencing developmental delay, children with multiple disabilities, and those with poor regulation (but otherwise typically developing).

Table 1. General skill development goals for young children that may be supported by assistive technologies

General development goals	Studies included in the review
Improving communication including communication strategies, communicative turn taking, responding to cues, communicating needs and wants, requesting, imitation	(Borgestig et al., 2017[60]); (Bourque and Goldstein, 2020[23]); (Chapin et al., 2021[26]); (Desideri et al., 2017[29]); (Grygas Coogle, Floyd and Rahn, 2018[34]); (Hughes-Roberts et al., 2019[69]); (Kossyvaki and Curran, 2020[37]); (Lorah and Parnell, 2017[39]); (Lorah, Miller and Griffen, 2021[40]); (Meeks, 2017[41]); (Thiemann-Bourque, McGuff and Goldstein, 2017[46]); (Yong et al., 2021[49])
Supporting social engagement including improving social communication, social competence, positive social interactions with peers, turn taking	(Cardon, Wangsgard and Dobson, 2019[25]); (Eden and Oren, 2021[31]); (Green et al., 2017[61]); (Kemp et al., 2019[35]); (Kouo, 2019[36]); (McCoy et al., 2017[70]); (Oh-Young et al., 2018[51]); (Pokorski et al., 2019[44])
Supporting general skill development including self-regulation, engagement with daily activities, schedule and routine following, pretend play, picture identification, action labelling, facilitating joint attention	(Borgestig et al., 2017[60]); (Cao et al., 2019[24]); (Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]); (Dueñas, Plavnick and Goldstein, 2021[30]); (Hall Pistorio, Brady and Morris, 2019[62]); (Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52]); (Schebell et al., 2018[56]); (Syrdal et al., 2020[45])

Communication was focused in the main on imparting and exchanging information by speaking. ATs were seen to support activities such as social interaction (e.g. Al-Zboon and Al-Dababneh (2021[71]); Borgestig et al. (2017[60])), communication strategies (e.g. Chapin et al. (2021[26]); Chazin et al. (2018[67])) and specific social activities (e.g. Bourque and Goldstein (2020[23]); Kemp et al. (2019[35])). Dueñas, Plavnick and Goldstein (2021[30]) reported on video exemplars used to create playsets for children with ASD to model social initiations. Central to these opportunities to explore communication was feedback. Eden and Oren (2021[31]) identified video playback and auditory feedback as essential for interactivity. Play-based contexts were incorporated into the design of some ATs. For example, Gevarter, Horan and Sigafoos (2020[33]) looked to play-based contexts, employing customisable speech generation with photographic visuals and touch input to support the complex communication needs of pre-schoolers with ASD.

A small number of papers focused on the possibilities for AT to support interactions between and among a child with special needs and others. Bourque and Goldstein (2020[23]) looked to AT to support mainstream peers to communicate with children with ASD. Video provided ways to model behaviours and present content to research participants (Cardon, Wangsgard and Dobson, 2019[25]; Chapin et al., 2021[26]; Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]; Dueñas, Plavnick and Goldstein, 2021[30]; Green et al., 2017[61]; Thompson and Johnston, 2017[47]). Green et al., (2017[61]) reported that the use of individualised videos provided models of target behaviour to support positive interactions with peers. Chai (2017[57]) and Chazin et al. (2018[67]) looked specifically to child and adult interactions when mediated by technology. Grygas Coogle et al. (2018[72]) found that novice teachers could be coached in real-time using an iPad, Skype and a Bluetooth earpiece as they worked with children with communication delays. The use of video will be discussed in greater detail in the section focused on technological design.

The remaining articles (42%) focused on specific types of interactions in ECEC settings and learning outcomes (Table 2), including:

- in-class response behaviours
- improvements in vocabulary, phoneme use, literacy and numeracy
- child behaviour and engagement
- staff practices.

Of these, the target demographic was broad, capturing six different disabilities. Applications of AT included the development of software or apps for the specific purpose of skill development. For example, Aunio and Mononen (2018[73]) focused on developing a game to support numeracy skill development while Cassady, Smith and Thomas (2018[66]) and Boyle et al. (2021[50]) focused on AT support for reading acquisition. Grygas Coogle, Floyd and Rahn (2018[34]) found that engaging in partnered dialogic reading was more effective with technology to support children with ASD learn vocabulary. Some researchers also found novel ways to use readily accessible software (such as PowerPoint) to focus on specific skill development in supportive ways for their focus groups of children (e.g. Hall Pistorio, Brady and Morris (2019[62]); Ozen, Ergenekon and Ulke-Kurkcuoglu (Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52])).

Table 2. Interactions in ECEC settings and learning outcomes that may be supported by assistive technologies

Interactions and learning outcomes	Studies included in the review
Supporting the development of literacy and numeracy skills including reading, vocabulary, word production and usage, acquisition of phonemes, phonics, expressive vocabulary, language comprehension, speech production, oral language skills, numeracy, emerging mathematics skills	(Aunio and Mononen, 2018[73]); (Boyle et al., 2021[50]); (Cassady, Smith and Thomas, 2018[66]); (Chai, 2017[57]); (Dennis and Whalon, 2021[55]); (Desideri et al., 2017[29]); (Dueñas, Plavnick and Goldstein, 2021[30]); (Fuglerud and Solheim, 2018[32]); (Gevarter, Horan and Sigafoos, 2020[33]); (Grygas Coogle, Floyd and Rahn, 2018[34]); (Kong, Carta and Greenwood, 2021[64]); (Lim, Ellis and Sonnenschein, 2022[38]); (O'Brien, Mc Tiernan and Holloway, 2018[43]); (Rivera et al., 2017[53]); (Segal-Drori, Kalmanovich and Shamir, 2019[68]); (Shamir, Segal-Drori and Goren, 2018[59])
Improving behaviour including behaviours on behaviour intervention plans, classroom and school behaviour, academic responsiveness, enabling greater participation in educational activities	(Chazin et al., 2018[67]); (Encarnação et al., 2017[58]); (Gunderson et al., 2017[74]); (Muharib et al., 2019[42]); (Regan and Howe, 2017[63]); (Schulz et al., 2020[65]); (Thompson and Johnston, 2017[47])
Supporting ECEC staff including engagement in classroom routines, implementing behavioural interventions, supporting autonomous participation, communication strategies, skill development, improving simultaneous prompting	(Coogle et al., 2021[27]); (D'Agostino, Douglas and Horton, 2020[54]); (Encarnação et al., 2017[58]); (Grygas Coogle et al., 2018[72]); (Syrdal et al., 2020[45]); (Tunc-Paftali and Tekin-Iftar, 2021[48])

Computer-assisted instruction, specifically using visual supports, were identified throughout the archive. For example, Hall Pistorio, Brady and Morris (2019[62]) found that a visual timer helped learn specific scheduling skills. O'Brien, Mc Tiernan and Holloway (2018[43]) found that customised images to teach letter-sound correspondences served as a positive intervention for children with ASD. Likewise, Ozen, Ergenekon and Ulke-Kurkcuoglu (2017[52]) found images improved receptive identification for children with developmental disorders.

It seems that intervention efforts can be largely divided into two focused outcomes: first, those that are focused on accessibility, that is, providing children with the necessary communication, social competence and attention towards creating an interaction space that caters for the characteristics of young children with special needs. These skills are not only necessary for the classroom but have societal influence beyond formal education. Second, those that centre on education/curriculum outcomes and thus appear to be more focused on equity – employing deliberate design, pedagogical and curriculum strategies that recognise and support the abilities of children with special needs toward curriculum attainment. There were clear messages across the archive around the importance of technology applications being age-appropriate, readily available and socially acceptable (Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]).

Some studies included an examination of teaching practices, with seven papers including a focus on ECEC teachers' use of AT. Pre-school teachers were explicitly identified in three of the papers (Coogle et al., 2021[27]; D'Agostino, Douglas and Horton, 2020[54]; Tunc-Paftali and Tekin-Iftar, 2021[48]). Grygas Coogle et al. (2018[72]) referred to novice teachers and Encarnação et al. (2017[58]) referred generally to teachers. Specific roles for teachers were identified by Al-Zboon and Al-Dababneh (2021[71]) who focused on those working in early intervention programmes and Coogle et al. (2021[27]) who identified those in inclusive classrooms. With only relatively few studies that focus on ECEC teacher practice, research into the professional development of educators' use of AT in terms of child outcomes is also limited. However, it is noted that more studies on educator perception were found in the search for this review but did not capture child-centred outcomes and therefore are not included in the report.

2. Environmental and civic considerations

This section identifies important environmental considerations that have emerged from the literature. It covers aspects such as how the technologies are deployed in different settings; the structures, procedures, and expectations that influence AT use within early childhood settings; and how different actors engage with and through the technology (e.g. staff, parents, children, technology developers). The section also considers civic structures that facilitate interactions with assistive technologies in ECEC. It examines the impact of the wider community, professional development and training, as well as policy conventions and guidelines.

The global coverage of research into assistive technology to support young children with special needs spans the United States, Europe, the Middle East and Asia, and reflects the research efforts in the use of AT for these regions. More than half of the studies within the archive (31) were conducted in the United States. Four studies were conducted in the United Kingdom, three studies were conducted in Israel and Türkiye, and two studies were conducted in Italy. Australia, China, Finland, Ireland, Jordan, New Zealand, Norway, Portugal, Singapore and Sweden each hosted one study in the archive. Notably, there's limited representation from the Global South. Most of the studies reported funding, primarily from government bodies, for the research suggesting increasing recognition internationally of the importance of AT.

Almost two-thirds of the archive (33 studies) reported on AT deployed in mainstream schools or pre-schools to support specific child needs. Assistive technologies, while used to support individual learning, were mostly incorporated in these mainstream inclusive classrooms for broader use across the class (for example, Boyle et al. (2021[50]); D'Agostino, Douglas and Horton (2020[54]); Kemp et al. (2019[35]); Schulz et al. (2020[65]); Thiemann-Bourque, McGuff and Goldstein (2017[46])) with some studies reporting special education classrooms within the mainstream school (for example, Grygas Coogle, Floyd and Rahn (2018[34]); Kouo (2019[36]); Schebell et al. (2018[56]); Thompson and Johnston (2017[47])). One study (Oh-Young et al., 2018[51]) also examined assistive technologies on the playground. A smaller number of studies (10) reported on AT within a specialised school or pre-school. In these contexts, assistive technologies were incorporated within classrooms (for example, Muharib et al. (2019[42])) but also used in a therapy room (for example, Yong et al. (2021[49])). Sites outside school or pre-school contexts included a public health location (Desideri et al., 2017[29]), an Early Intervention Centre (Lim, Ellis and Sonnenschein, 2022[38]); university-based settings (Cardon, Wangsgard and Dobson, 2019[25]; Chazin et al., 2018[67]; Pokorski et al., 2019[44]) or within specific programmes (for example, Chapin et al.'s (2021[26]) early education programme and Dueñas, Plavnick and Goldstein's (2021[30]) early intensive behaviour intervention programme). Most of the time, research reports the use of AT between child and educator or between and among children. AT is often positioned as the mediator for these interactions that occur within ECEC settings and existing time structures (a school day or a specific lesson time) and within procedures and expectations set by the ECEC staff in control.

The capacity of the ECEC community to engage in dialogues and undertake activities involving AT that intentionally benefit children is evident across the archive. Generally, the AT is used for an adult-defined purpose (most often educator) and the targeted child(ren) engage with the AT for that defined and intended purpose. The "potential" of AT to change and support the learning trajectories of children was argued across the archive. Assistive technologies were seen to provide inclusive experiences for children with special needs (for example, Boyle et al. (2021[50]) and the "promise" of AT for supportive peer involvement was recommended by many studies (for example, Bourque and Goldstein (2020[23]); Cardon, Wangsgard and Dobson (2019[25]); Chai (2017[57]); Gevarter, Horan and Sigafoos (2020[33]); Green et al. (2017[61]); Kemp et al. (2019[35]); Lorah, Miller and Griffen (2021[40]); McCoy et al. (2017[70])).

The need for collaboration between parents, ECEC staff and developers is essential to ensure interventions are understood more broadly than individual classrooms for individual student needs. Borgestig et al. (2017[60]) identified that while AT can offer high levels of support for children most in need, this can only happen when there is collaboration and a shared agenda and understanding between key stakeholders. Pokorski et al. (2019[44]) urged that those designing educational programmes and policy recommendations must consider results from research and syntheses to ensure translation of evidence. While there was success across the archive with bespoke programmes that responded to individual needs, there was also a call for a "team" approach where interests and needs are coupled with expert theory and practice to inform a more sustainable intervention. Researchers called for additional funding to continue projects to improve practice (for example, Al-Zboon and Al-Dababneh (2021[71]); Encarnação et al. (2017[58])), increase teacher training (for example, Chazin et al. (2018[67]); D'Agostino, Douglas and Horton (2020[54]); Kossyvaki and Curran (2020[37])) and provide recommendations to extend research findings (for example, Kouo (2019[36]); Lorah, Miller and Griffen (2021[40]); Syrdal et al. (2020[45])).

Specific technologies were identified to support a range of targeted learning needs, with a sense of increased potential moving forward. For example, Cao et al. (2019[24]) identified the potential for robots to take on roles as social mediators between people with ASD and therapists providing greater access to required support and Hughes-Roberts et al. (2019[69]) identified the potential for robots in the pursuit of learning goals for children with intellectual disabilities. Cassady, Smith and Thomas (2018[66]) identified the potential for computer-assisted instruction to support second language learners and Dennis and Whalon (2021[55]) argued customisable apps can support vocabulary learning. The following section provides further detail on AT design to support young children with special needs.

3. Technology design to support children with special needs in ECEC

The section outlines the hardware and software that is being used to support young children with special needs in early childhood settings. It identifies the strategies embedded within these technologies and summarises the design features of AT that improve access to and usability of digital tools to support the special needs of young children. Table 3 summarises the various software-hardware combinations employed across our archive, providing examples of how the software has been used to assist young children with special needs. One study, which focused on hardware and software in general terms, gathering information on the use of assistive technology in teaching children with developmental delays via a survey of teachers (Al-Zboon and Al-Dababneh, 2021[71]), has not been included in the table below. This survey found that teacher beliefs about AT impacted use within classrooms and demonstrated the importance in providing additional resources, training and assistance to support greater uptake and effective use of these technologies.

Table 3. Software-hardware combinations for assistive technologies in ECEC settings

Software-hardware combinations			No. papers
Video	Video recording software, video playback and sharing used for peer modelling and dynamic visual display	Tablet	7
		PC/Laptop	2
Specialist software	Aligned with specific hardware (e.g. robots), voice recognition, gaze tracking	Robots	6
		Specialist Device	3
Software app	Child-oriented software application, either commercially available or developed by researchers	Tablet	6
		PC/Laptop	2
Productivity software	Video conferencing (e.g. Zoom), presentation software (e.g. PowerPoint), timers, addition of accessibility add-ons	Tablet	4
		PC/Laptop	2
		Headphones	3
Speech generation	Support for communication, touch input aligned with voice output	Tablet	6
		Specialist Device	2
E-book	For supporting literacy, reading and numeracy skills	Tablet	4
		Headphones	1
Digital games	Word and singing games, finding items	Tablet	2
		PC/Laptop	1

3.1. The use of video as assistive technology

Video, delivered via a Tablet (*n*=7) or PC/Laptop (*n*=2), was used in nine studies to support young children with special needs. The five studies that focused on supporting social skill development and peer interactions (Cardon, Wangsgard and Dobson, 2019[25]; Green et al., 2017[61]; Kouo, 2019[36]; McCoy et al., 2017[70]; Oh-Young et al., 2018[51]) found video modelling to be an effective and inclusive intervention strategy with some caveats around generalisation and maintenance of improvements (Kouo, 2019[36]) and variations in effectiveness for different children (Green et al., 2017[61]; Oh-Young et al., 2018[51]). The use of video modelling was also used to support communication during turn taking (Chapin et al., 2021[26]), behaviour management (Regan and Howe, 2017[63]), and literacy development (Dueñas, Plavnick and Goldstein, 2021[30]), and the findings from these studies demonstrated positive outcomes. Asynchronous video sharing for feedback purposes was used in one study (Tunc-Paftali and Tekin-Iftar, 2021[48]) to coach teachers in the effective use of simultaneous prompting and was shown to be effective in acquiring and maintaining these skills.

The results indicate that peer-mediated video modelling can support social communication development in pre-school-age children with special needs (e.g. Cardon, Wangsgard and Dobson (2019[25]), Green et al. (2017[61])). The use of typically developing peers within videos may contribute to the overall imitation development of children with special needs, particularly those with ASD, and provide them with numerous opportunities to imitate the social interactions they observe. Video-based visual scene displays may also be effective in supporting joint attention and communicative turn taking (Chapin et al., 2021[26]). The type of video modelling provided might impact outcomes (e.g. priming, prompting, scene setting) and given overall positive outcomes, this is an important area for future research (Kouo, 2019[36]). The use of video modelling intervention strategies by practitioners may depend on feasibility and ease of implementation (Dueñas, Plavnick and Goldstein, 2021[30]) and there is evidence that teachers prefer more traditional intervention methods (Oh-Young et al., 2018[51]).

3.2. Robots for young children with special needs

Six of the papers reviewed for this report introduced robots as an AT to support young children with special needs, with four focused on children with ASD. Each of these studies used the robots to engage the children in interactions designed to support specific outcomes, with the robot serving as a replacement for, or in addition to, human interaction. In four studies, off-the-shelf Nao robots were programmed to engage children in activities designed to promote joint attention (Cao et al., 2019[24]), engagement (Desideri et al., 2017[29]; Hughes-Roberts et al., 2019[69]), and communication (Fuglerud and Solheim, 2018[32]; Hughes-Roberts et al., 2019[69]). These studies found Nao robots can be as effective as traditional teaching methods in promoting learning (Desideri et al., 2017[29]; Hughes-Roberts et al., 2019[69]; Fuglerud and Solheim, 2018[32]) and engagement (Cao et al., 2019[24]; Desideri et al., 2017[29]; Hughes-Roberts et al., 2019[69]; Fuglerud and Solheim, 2018[32]), and in some instances outcomes were improved. Three of these studies (Cao et al., 2019[24]; Desideri et al., 2017[29]; Hughes-Roberts et al., 2019[69]) were comparative, investigating young children's engagement with Nao robots as an alternative to teacher or other adult interaction. These studies showed promising outcomes, except for supporting joint attention. Similar encouraging outcomes were found using the Kaspar robot (Syrdal et al., 2020[45]), with positive results across sensory and communication domains for children with ASD. One study, which deployed specifically designed Lego Mindstorms robots, found they can be useful resources to support communication and manipulation activities (Encarnação et al., 2017[58]), but required additional adult support throughout the learning sessions. Teachers also identified the need for additional training to be effective. This system was also not useful for younger children (i.e. two-three year-olds) in the study. Desideri et al. (2017[29]) and Hughes-Roberts et al. (2019[69]) noted that outcomes from their research varied depending on the individual characteristics of the child, with some indication that younger children achieved fewer gains through this form of assistive technology. The feasibility and usability of robots in daily practice remain unclear, with studies typically requiring specialist knowledge to create the interventions being examined.

3.3. Highly specialised assistive technology

Highly specialised AT solutions, which include dedicated hardware (e.g. Cosmo units, Tobii hardware, iClickers) and software (e.g. gaze tracking, speech generation), were the focus of five papers reviewed (Borgestig et al., 2017[60]; Kossyvaki and Curran, 2020[37]; Schulz et al., 2020[65]; Thiemann-Bourque, McGuff and Goldstein, 2017[46]; Chazin et al., 2018[67]). Four of these studies (Borgestig et al., 2017[60]; Kossyvaki and Curran, 2020[37]; Thiemann-Bourque, McGuff and Goldstein, 2017[46]; Chazin et al., 2018[67]) were conducted with children with severe impairments and had the aim of improving social communication and engagement. While results showed positive outcomes, with an increase in activities (Borgestig et al., 2017[60]), engagement (Kossyvaki and Curran, 2020[37]) and communication (Thiemann-Bourque, McGuff and Goldstein, 2017[46]; Chazin et al., 2018[67]), outcomes tended to be moderate (Thiemann-Bourque, McGuff and Goldstein, 2017[46]; Kossyvaki and Curran, 2020[37]) and child-specific (Kossyvaki and Curran, 2020[37]; Borgestig et al., 2017[60]; Chazin et al., 2018[67]). Designed to provide a high level of support, such solutions required a high level of adult, teacher and/or researcher support (Borgestig et al., 2017[60]; Kossyvaki and Curran, 2020[37]) and ongoing training (Chazin et al., 2018[67]). The remaining study, which examined technology (e.g. iClickers) to support active responses for young students who require academic support in classroom settings, found that such systems may be effective in increasing academic performance and on-task behaviour (Schulz et al., 2020[65]).

The use of speech generation software was the focus of eight studies. While both Chazin et al. (2018[67]) and Thiemann-Bourque, McGuff and Goldstein (2017[46]) used specialist hardware in combination with speech generation software, six additional research studies (Gevarter, Horan and Sigafoos, 2020[33]; Bourque and Goldstein, 2020[23]; Lorah and Parnell, 2017[39]; Lorah, Miller and Griffen, 2021[40]; Muharib et al., 2019[42]; Yong et al., 2021[49]) employed standard tablet devices (e.g. iPads) for this purpose. All studies investigated how speech generation technology can support young children's communication, with six of the papers focused on pre-school children with ASD, and the remaining two (Chazin et al., 2018[67]; Yong et al., 2021[49]) including participants with other developmental disabilities. Results across the eight projects demonstrated the potential of speech generation for children with complex communication needs for improving the use of functional target vocabulary (Gevarter, Horan and Sigafoos, 2020[33]), engagement in peer communication (Bourque and Goldstein, 2020[23]), requesting behaviours (Muharib et al., 2019[42]; Yong et al., 2021[49]) and responding to educator cues (Lorah and Parnell, 2017[39]). Gevarter, Horan and Sigafoos (2020[33]) looked specifically at interface design to support communication outcomes. Comparative studies that examined "high-tech" (e.g. iPad with speech generation software) and "low-tech" (e.g. visual booklet) alternate communication devices demonstrated technology as an effective alternative to printed resources and that children with special needs can be empowered through different communication modalities (Chazin et al., 2018[67]; Yong et al., 2021[49]).

3.4. Using productivity software as assistive technology

Nine papers in our archive employed business productivity software to support young children with special needs. Five studies described the use of readily available presentation software (Grygas Coogle, Floyd and Rahn, 2018[34]) (O'Brien, Mc Tiernan and Holloway, 2018[43]; Thompson and Johnston, 2017[47]; Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]; Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52]) to enhance outcomes for young children with ASD (*n*=4) and for those with developmental delays (*n*=1):

- Delivery of multimedia experiences through text, images and audio (i.e. narration) to support vocabulary acquisition (Grygas Coogle, Floyd and Rahn, 2018[34]).
- Presentation of letter combinations to deliver a computer-aided instruction approach to teaching phonics (O'Brien, Mc Tiernan and Holloway, 2018[43]).
- Visual activity schedules enhanced with video modelling to teach pretend play skills (Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]).
- Delivery of multimedia experiences through text, images, audio and video (i.e. video modelling with the aim of decreasing the frequency of undesired behaviours (Thompson and Johnston, 2017[47])).
- Embedding images in a presentation to deliver a computer-aided instructional experience designed to acquire information via simultaneous prompting (Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52]).

Overall, findings from these studies demonstrated positive outcomes (O'Brien, Mc Tiernan and Holloway, 2018[43]; Dalgin-Eyiip and Ulke-Kurkcuoglu, 2021[28]; Ozen, Ergenekon and Ulke-Kurkcuoglu, 2017[52]), highlighting the effectiveness of specifically designed interventions delivered through familiar software applications. However, the two comparative studies (Grygas Coogle, Floyd and Rahn, 2018[34]; Thompson and Johnston, 2017[47]), found that while the results were positive, there was no evidence that a digital intervention was more effective than a paper-based strategy.

One additional study investigated the effectiveness of active noise cancellation delivered via headphones in altering or blocking auditory sensory input for children who exhibit hypersensitivity to environmental stimuli (Pokorski et al., 2019[44]). The research found that the use of headphones did not improve behaviours or engagement outcomes.

Three studies focused on ways of supporting ECEC teachers. One employed videoconferencing software delivered via a tablet to supplement online professional development (D'Agostino, Douglas and Horton, 2020[54]). It provided initial evidence that this additional support produced positive outcomes in the implementation of developmental behavioural interventions. Two studies examined supporting teachers through real-time audio-based e-coaching delivered via headphones (Grygas Coogle, Floyd and Rahn, 2018[34]; Coogle et al., 2021[27]). The use of real-time audio-based e-coaching for teachers was shown to be beneficial, with teachers indicating it enhanced the effectiveness and frequency of communication (Grygas Coogle, Floyd and Rahn, 2018[34]) and increased their use of communication strategies (Coogle et al., 2021[27]) as they worked with children with special needs.

3.5. The use of child-centred apps

Eight papers in our archive examined the use of child-centred software applications delivered via tablet (*n*=6) or PC/laptops (*n*=2) to support young children with special needs. Four studies examined the use of apps to support the development of young children's literacy skills (Cassady, Smith and Thomas, 2018[66]; Chai, 2017[57]; Dennis and

Whalon, 2021[55]; Rivera et al., 2017[53]). While results were generally positive (Chai, 2017[57]; Dennis and Whalon, 2021[55]; Rivera et al., 2017[53]), these studies demonstrated that outcomes vary from child to child and may depend on the ability to create customisations relevant to the child (Dennis and Whalon, 2021[55]; Rivera et al., 2017[53]). Results from the comparative study by Cassady, Smith and Thomas (2018[66]) may support this finding; it found no significant difference in outcomes for those children who used off-the shelf, non-adapted literacy learning software compared to a control group.

The four other studies were focused on skill development more generally, including supporting increased engagement (Gunderson et al., 2017[74]), social competence (Eden and Oren, 2021[31]), improving spoken language skills (Meeks, 2017[41]) and teaching action labelling (Schebell et al., 2018[56]). Once again outcomes were positive and demonstrated the value of customising experiences through specifically designed multimedia software (Eden and Oren, 2021[31]) or the ability to include target stimuli identified by practitioners who know the children they are working with very well (Schebell et al., 2018[56]). The one comparative study in this group which used non-adapted off-the-shelf instructional software (Gunderson et al., 2017[74]) showed no significant difference in outcomes compared to a more traditional instruction method.

3.6. E-books and games for children with special needs

Five studies examined the effectiveness of e-books in supporting learning and skill development and an additional three studies investigated the outcomes of playing digital games. Three e-book studies focused on literacy outcomes, including improvements in vocabulary (Boyle et al., 2021[50]), language retention (Shamir, Segal-Drori and Goren, 2018[59]), and oral language skills (Kong, Carta and Greenwood, 2021[64]). The study conducted by Kong, Carta and Greenwood (2021[64]) focused on interactive listening sessions delivered via headphones. In addition, one study examined the effectiveness of an interactive digital game to support the production of target words (Lim, Ellis and Sonnenschein, 2022[38]). All four research projects demonstrated effectiveness in achieving positive outcomes. Boyle et al.'s study (2021[50]), which applied transition to literacy techniques, demonstrated how materials can be developed using classroom storybooks allowing for the provision of inclusive classroom experiences that highly engage children with special needs. Kong, Carta and Greenwood's research (2021[64]) is underpinned by a multi-tiered system of support, and both these projects demonstrate the importance of assistive technologies being based on strong theoretical and pedagogical foundations.

Two studies examined mathematics outcomes that result from using an e-book (Segal-Drori, Kalmanovich and Shamir, 2019[68]) and a digital game (Aunio and Mononen, 2018[73]). The outcomes from the e-book study were promising with evidence of significant improvement for the intervention group in the measures of addition and ordinal numbers (Segal-Drori, Kalmanovich and Shamir, 2019[68]). While the digital game did not appear to improve outcomes for the intervention group over the control group (Aunio and Mononen, 2018[73]), a within-group analysis showed significant improvement for those children with the lowest scores at baseline. With respect to more general skill development, research by Hall Pistorio, Brady and Morris (2019[62]) examined the use of an e-book, implemented through presentation software, to assist in developing skills around self-regulation, and a study by Kemp et al. (2019[35]) investigated a digital game to support turn taking. Both studies resulted in enhanced outcomes for young children with special needs.

Positive outcomes related to e-books demonstrate their value beyond supporting literacy development, with the thoughtful implementation of a literacy-based intervention promoting emergent mathematics skills (Segal-Drori, Kalmanovich and Shamir, 2019[68]) and self-regulation (Hall Pistorio, Brady and Morris, 2019[62]). The research by Hall Pistorio, Brady and Morris (2019[62]) demonstrated the value of autonomously delivered visual and audio cues to assist with on-task behaviour and self-regulation.

Case studies of effective practice

Bringing together the components of the activity theory approach, this section identifies three case studies that identify and consolidate the "what", "why" and "how" of assistive technology use in ECEC. The case study examples are intended to highlight the collective factors, articulated through an activity system perspective, that influence positive outcomes.

1. Case Study 1: Video-enhanced activity schedules for children on the autism spectrum

A research study by Dalgin-Eyiip and Ulke-Kurkcuoglu (2021[28]) was designed to evaluate the use of video-enhanced activity schedules to support the acquisition, maintenance and generalisation of schedule following and pretend play skills for young children with ASD.

1.1. What was implemented

Digital activity schedules were the assistive technology investigated in the study. Typically, a visual activity schedule is a set of pictures used as prompts to support the flow of activity (McClannahan and Krantz, 1999[75]). The schedules used for this project were designed and developed by the research team and delivered during the interventions using a laptop computer running Microsoft PowerPoint. Three pretend play scenarios were incorporated into the study and each of these was broken down into a series of steps through a task analysis process. Representative photographs of each pretend play skill were taken and transferred into the presentation software, with one image included on each presentation slide. An additional set of visual activity schedules were developed for each of the pretend play scenarios, with each of these incorporating peer video modelling instead of still images. These videos involved peers modelling pretend play as a series of step-by-step skills that reflected the steps in a corresponding visual activity schedule.

1.2. Why the study had this focus

Research has shown that the pretend play of children with ASD is qualitatively different from the play of typically developing children (Rutherford et al., 2007[76]). Children with ASD exhibit fewer and simpler pretend play skills (Barton, 2010[77]) and these differences may limit a child's engagement in play activities with peers and complicate communication and social acceptance. Learning pretend play skills in developmentally appropriate and socially valid ways may lead to improved interactions with peers.

Studies have demonstrated the effectiveness of visual activity schedules in supporting skill development for individuals with ASD (e.g. MacDuff, Krantz and McClannahan (1993[78]); Blum-Dimaya et al. (2010[79])). They can be useful for teaching the transitions between and within activities and implementing graduated guidance as a support mechanism (e.g. MacDuff, Krantz and McClannahan (1993[78]); Çuhadar and Diken (2011[80])). The use of video modelling as an AT strategy has been widely researched. Video modelling is based on Bandura's observational learning theory and the use of peer, self and adult video modelling has been shown to be a useful technique for teaching children with ASD (Steinbrenner et al., 2020[81]). This strategy, which incorporates modelling and imitation of an activity, interaction or skill, has been effective in improving social interactions and pretend play (e.g. Charlop et al. (2010[82]); Boudreau and D'Entremont (2010[83])). The current study incorporates both visual activity schedules and video modelling as techniques to support young children with ASD in developing pretend play skills by breaking the process down into a sequence of activities.

1.3. How the intervention was implemented and managed

The development of the pretend play activities presented to children in the study was based on a process that involved:

1. Creating a list of pretend play scenarios that considered the characteristics of the children involved in the study, as well as skills identified as important in the ASD literature.
2. Refining the list through consultation with teachers and parents.
3. Employing expert review to formulate tasks associated with each pretend play scenario and skill set.

During the intervention, the children were asked to work through a sequence of events that required them to direct their attention to the computer screen, select and open an activity photo that was part of the activity schedule and complete a physical pretend play task using the resources provided for the session. In a successful session, interaction with a given activity schedule photo was followed by initiating the activity with play materials, with the child able to independently work through the task sequence. Positive reinforcement was provided if the child succeeded in performing a target pretend play skill. Training for this independent experience of working through the schedule and imitating play was provided through video modelling and expert graduated guidance. A child would watch the video and then they were supported to use the schedule and engage in pretend play tasks through prompting, cues and reinforcement provided by the expert.

1.4. Lessons learned

Results show that over time, the intervention was effective for all children, and they were then able to engage independently with the activity schedule and perform pretend play tasks. The study also found that the children maintained their ability to perform these activities one, two and four weeks after the intervention. Surveys with special education teachers and parents elicited positive responses regarding the acceptability of the intervention and its outcomes.

The key features of this study that supported success are:

- Solid foundation in educational theory and practice.
- Collaboration with teachers, parents and experts.
- Off-the shelf hardware and software used to create a bespoke intervention.
- Technological solution used as a vehicle for the intervention and augmented by expert support and training.

The training activity was heavily guided by the expert adult and the extent to which this is a viable technique that can be readily employed across the ECEC landscape may be questioned. However, many features of this intervention may be considered in mainstream contexts.

2. Case Study 2: The use of an e-book to support learning

Research conducted by Segal-Drori, Kalmanovich and Shamir (2019[68]) assessed the effectiveness of an electronic book (e-book) for promoting emergent mathematics skills. This comparative study included over 100 children aged between four and seven and included those at risk for learning disabilities and those with typical development.

2.1. What was implemented

The study intervention used an educational e-book that included familiar characters and actions relevant to the experiences of young children. It was developed as an experimental tool and designed by the research team. The story was read by a narrator, used age-appropriate language and narrative structure, and included clear instructions and appropriately sized text accompanied by illustrations. The book allowed the child to independently control nonlinear multimedia functions, such as animations and hotspots and included automatic, interactive and content to support story comprehension. The e-book could be read in three different modes, a *read-study-only* mode that enables reading or listening to the book without interactive activations, a *dictionary* mode, which includes a dictionary and allows readers to activate hotspots that provide explanations for challenging words, and a *read-with-hotspots* mode, which is aimed at strengthening the mathematics skills relevant to the story's mathematics content. These activations enable repeated exposure to the foundations of addition and ordinal numbers.

To support learning, a reader could click on hotspots and access screens as often as desired, but only after reading or listening to the text on each page. After the narrator finished reading each page, an animation appeared which included a verbal and visual explanation of a mathematics concept. Animations are followed by the appearance of a hotspot that the reader can activate should they want to experience the explanation again.

2.2. Why the study had this focus

The e-book experience is designed to create a motivating reading experience that arouses a child's curiosity by describing familiar characters and actions and providing engaging interactive elements that can be activated independently. Through E-books that include hotspots that initiate an auditory or visual effect, the reader becomes an active participant in the storytelling (Shamir and Korat, 2006[84]). This type of child-controlled environment has been demonstrated to increase learner motivation and interest and support different leaner preferences (e.g. Antonenko and Niederhauser (2010[85]); Scheiter and Gerjets (2007[86])). Negative outcomes that have been shown to occur, such as information overload and distraction, have been alleviated in this study through careful e-book design that is based on 20 years of research in the field. The rationale for introducing mathematics concepts via storytelling is theory- and evidence-based, referencing research on the use of narrative frameworks for retaining knowledge and the benefits of embedding mathematical context within a meaningful context.

The study identifies the effectiveness of appropriately designed e-Books in supporting skill development for typically developing children. There is also evidence that this type of experience may support those at risk for learning disabilities. A comparative methodology was used in this research to examine the effectiveness of one software application for children with different needs, abilities and interests. The study flags the importance of identifying differences in outcomes and benefits for those children who are at risk for learning disabilities in comparison to those children with typical development.

2.3. How the intervention was implemented and managed

This study included 51 young children who had been identified as exhibiting developmental delays that placed them at risk for learning disabilities (LDs) and 56 children with typical development (TD) enrolled in mainstream education classes. The procedure included pretesting all participants to assess their cognitive level (verbal and nonverbal) and pretesting selected participants to assess foundational addition and ordinal number skills. The two groups were randomly divided into sub-groups, an intervention group involved children engaging with the educational e-book activity, and a control group in which the children participated in the regular kindergarten programme with no e-book intervention. Participants at risk for LDs and those with TD were randomly divided into the intervention and experimental and control groups.

Children engaged in the intervention study had five, 25-minute independent sessions with the e-Book. In the first and second sessions, they read using the *read-story-only* mode. In the third session, they used the *dictionary* mode, and in the final two sessions, they used the *read-with-hotspots* mode. Post-intervention involved the administration of the same assessment tests as those carried on prior to the intervention. The findings of the study show significant improvements in foundational addition and ordinal number skills for both children at risk for LDs and those with TD after the e-book intervention.

2.4. Lessons learned

- Effective AT design involves end users, educators, and other experts (e.g. therapists, researchers).
- Flexible and adaptable AT can be beneficial for a broad population of children.

- Children with special needs benefit from multisensory digital learning experiences that include diverse representations and multiple communication channels.
- Translating good technology design features into practitioner guides and checklists should be prioritised through ECEC policy initiatives.

As highlighted in the paper, the choice of quality e-books is not necessarily straightforward. How research knowledge and expertise are effectively translated into information that can be accessed, interpreted and applied by ECEC policy makers and staff remains an ongoing challenge. Relatedly, it is unclear how such expertise in the design of quality digital products and experiences for young children with special needs can be readily adopted by industry.

3. Case study 3: Supporting teacher practice

A research study conducted by Coogle et al. (2021[27]) investigated the effect of real-time feedback delivered to special education teachers as they engaged with young children with special needs.

3.1. What was implemented

Real-time voice feedback was provided to special education teachers by an expert coach as they interacted with young children with ASD. The feedback was designed to improve interactions allowing children opportunities to practice and generalise important target skills via everyday routines. This feedback was delivered through a Bluetooth-enabled earpiece connected to teleconferencing software running on a tablet device.

3.2. Why the study had this focus

Naturalistic instruction is an evidence-based practice that teachers can use to provide opportunities for children with special needs to learn and practice skills during everyday routines (Grisham-Brown, Hemmeter and Pretti-Frontczak, 2005[87]). A core feature of naturalistic instruction is intentionally embedding *antecedents*, which are opportunities to practice target skills, and consequences, which are responses to a child's behaviour. Importantly, target skill development can be aligned with a child's Individual Education Plan (IEP) and embedding antecedents and consequences that align with IEP goals across routines offer multiple opportunities for the child to practice and generalise target skills (Johnson, Rahn and Bricker, 2015[88]). Given the significance of achieving communicative goals for many children with special needs, this research focuses specifically on naturalistic instruction that embeds communicative antecedents and consequences.

Although research has identified the benefits associated with embedding antecedents and consequences, children with special needs often receive limited opportunities to attain target skills. Research has shown that teachers need support in using these practices, and professional development that is interactive, linked to target outcomes, collaborative and ongoing is effective in changing practice (Hemmeter et al., 2011[89]). Performance-based feedback is a common interactive coaching strategy, and in recent years research has focused on the use of technology (e.g. email) for delivering such feedback. Creating tighter and more immediate feedback loops may improve practice outcomes and this research project incorporates "in-the-moment" performance feedback provided to teachers while they are interacting with children.

3.3. How the intervention was implemented and managed

This study involved young children with ASD and their special education teachers. The children's IEP goals related to expressive communication were selected as the focus of the study. Specific strategies that included target antecedents and target consequences that aligned with an IEP communicative goal for each child were identified and documented (e.g. choice-making through providing choices to the child to create a communication opportunity).

Intervention sessions involved the special education teacher and the child they were paired with. Each of the five 6-minute sessions was designed to focus on a specific communication strategy for a given child, and prior to a session, teachers would watch a 15-minute narrated presentation that summarised communication strategies. Each teacher was provided with a tablet device and a Bluetooth earpiece and at the start of the session the teacher called an appropriately trained coach using teleconferencing software. The researchers used this communication channel to provide real-time, technology-enhanced performance feedback (TEPF) during the intervention session. The teacher would engage the child participant in an activity and feedback that was specific, immediate, affirmative, and corrective (as needed) was provided in real-time by the coach. Teachers might also be prompted if they were not using communication strategies spontaneously.

The study found a positive effect of real-time TEPF on teaching practice and special education teachers involved indicated that they felt it was a feasible and effective strategy. In addition, the research demonstrated some positive expressive communication outcomes for the children involved in the study. Given the short duration of the study and the focus on teaching practice rather than learning outcomes, this result provides preliminary evidence of positive change that may occur because of this teacher professional development.

3.4. Lessons learned

- Appropriately designed and implemented training leads to positive outcomes for children with special needs.
- Real-time interactive training contextualises professional development and connects teaching activities with concrete actions and informative feedback.
- Effective AT links evidence-based teaching practice with the individualised goals of children with special needs.
- Expert coaching is a highly effective professional development strategy.

This case study highlights the value of real-time coaching delivered via off-the-shelf technology to educators during interactions with children with special needs. While the approach appears intensive and requires specific coaching expertise, positive outcomes were achieved after just 45 minutes of coaching delivered through an introductory video and five relatively short interactive sessions. Logistical challenges associated with this type of intensive activity might be offset by the relatively short duration, limiting the cost and disruption to teaching practice. Further cost-benefit analysis of this innovative approach to professional development by ECEC policy makers and leaders would be beneficial.

Discussion

The discussion brings together the key points from the Findings and Case Studies sections to outline the conditions for success in using assistive technologies to support children with special needs. Equitable access for all children to enable them to fully participate in ECEC learning experiences is central to policy and practice. Many of the papers in the archive reference policy and practice in setting the scene for the research and outlining the approach to the research undertaken. While much of the research is focused on small groups of children (i.e. less than ten), the rigour of studies is maintained through robust theoretical grounding, appropriate research study design and accurate reporting of outcomes.

Our analysis of research in the field confirms the complex landscape that policy makers and practitioners face when making decisions regarding assistive technologies for young children with special needs. There is not one technological solution that is well aligned with a particular special need. As an example, while research on advanced speech generation technologies is generally focused on encouraging communication, the review also identified their use in improving behaviour and supporting literacy skill development. E-books, which may primarily be seen as a literacy tool, were shown to be effective in encouraging self-regulation and in supporting emerging mathematics skills. In addition, in many instances outcomes tend to be child-dependent; a solution that works well for one child, may not be particularly effective for another. Given this complexity, it is important to connect educational practice in terms of *purpose and outcomes* and *expertise and environment* with technological features that focus on *usability and social validity*, along with *adaptability and personalisation*.

1. Purpose and outcomes

A clear purpose and rationale for the use of any assistive technology are essential. As identified through our review, this purpose may be aligned with general skill development (e.g. communication, behaviour) and/or have a specific educational focus (e.g. supporting the development of literacy skills). In providing AT support to ensure participation in ECEC on an equitable basis, the individual needs and unique requirements of young children with special needs must be considered. Any rationale for inclusive AT use needs to reflect relevant academic, social, emotional, physical and/or psychological requirements to effectively cater for a child with special needs. Analysing AT experiences in terms of existing individualised education and/or behavioural plans may be an effective way of ensuring that they align with the needs of a child or group of children with special needs.

As identified in Table 1 and Table 2, the research studies reviewed included varied goals and objectives. These goals could easily be adapted by educators and practitioners in their use of assistive technologies. In defining the purpose of AT use and the associated outcomes, ECEC educators should identify the child(ren) to be supported taking into consideration the number of children who will be using the technology, whether activities will involve children with typical development alongside those with special needs, and the type(s) of support required. While outcomes may be quite specific (e.g. improving the acquisition of targeted phonemes), AT experience design should take into consideration additional developmental, pedagogical and contextual factors, and this requires expertise and experience. How we effectively deploy ATs so that they can be used, enjoyed, and valued by *all* children in a class is of particular importance when considering the social validity of ATs and their ongoing acceptance in ECEC. The following two sections outline considerations from this perspective.

2. Expertise and the ECEC environment

Our review calls for a focus on AT beyond just the immediate need identified for a child or group of children. While this initial need is important, so too is its connection to an underlying educational learning philosophy and pedagogical approach to the learning environment within which it is to be incorporated. Many of the papers in the archive referenced evidence-based practice, learning theories and special education pedagogy. The use of AT in ECEC is most effective when based on solid theoretical and practice-based foundations. Tensions between a technology-push approach (i.e. using technology for the sake of the technology) and the theory and practice of ECEC can be more easily resolved by an approach centred on children, context and pedagogy, in which those factors are articulated prior to consideration of AT support. Opportunities for educators to share experiences, solutions and findings in a community of practice are not only supportive but build capacity across the profession.

There is a need to focus on ecological validity to ensure the design of AT is consistent with and responsive to the context of students and early childhood education. There was evidence across the archive of AT use for both general skill development and for specific educational outcomes; both equally as important. ECEC staff are uniquely positioned through their understanding of child development, learning goals (often mandated through curriculum) and pedagogical practices. Staff expertise can contribute to content development for learning needs and implement AT through informed decisions to best support the child(ren). Across the archive, there are many examples of positive AT interventions that involve the expertise of educators, parents and/or therapists in their design and execution, emphasising the importance of stakeholder engagement. They also draw other children into the experience (e.g. via peer video modelling) to create richer experiences. Acknowledging expertise is essential in the incorporation of AT within educational settings to ensure it is appropriate to the intended learning, responsive to the child(ren) and conducive to the educational environment.

Many of the papers in our review profile interventions that while complex, are small in scale. These showcase positive findings and benefits to their participants, however, there is unrealised potential. Bringing research findings together, responding to identified needs and drawing upon expertise from those who work with children (educators, allied health, and families) will enable a wider impact to inform practices, guidelines and policies.

3. Usability and social validity

From a technological perspective, for assistive technologies to be effectively implemented in ECEC they need to be accessible, usable and engaging for end users (e.g. children and staff). Usability takes into consideration how well AT accommodates user needs and contexts. While there are many examples of AT solutions that achieve positive outcomes across the review archive, a majority of the studies are tightly controlled and managed by research teams. While this is understandable given the requirements of research in terms of rigour, reproducibility and replicability, is not helpful when assessing the readiness of AT solutions to be used independently within ECEC contexts. This difficulty suggests that the use of child-oriented commercially produced software solutions such as digital games and e-books may be most effectively deployed in ECEC. However, as outlined in the section above, the extent to which these can be successfully used by children with special needs should be assessed on a case-by-case basis. It also highlights the importance of appropriate professional development and training as part of the process of implementing AT in early childhood settings.

In assessing the usability of a software application for children with special needs, the Universal Design for Learning (UDL) Guidelines developed by CAST, a non-profit research and development organisation (see https://udlguidelines.cast.org/ for details) are a useful starting point. These guidelines identify criteria for engagement, representation, and action and expression that can be applied to software to identify any barriers to learning for children with special needs. The benefit of using commercially available software that follows UDL principles is that it may be deployed across an ECEC setting and used by multiple children with varying needs, skills and abilities. Based on our review, there is evidence of research that has resulted in guidelines for specific software applications (see Case Study 2 on e-books) and these guidelines may also be applied by educators in their assessment of commercial software applications.

Across the archive there were examples of AT experiences developed using productivity software such as presentation, video editing and teleconferencing applications. These AT experiences were generally bespoke, addressing specific needs and goals of individual children with special needs (e.g. Case Study 1). As individualised interventions, these AT solutions can effectively incorporate expertise from educators and healthcare professionals and embody pedagogical approaches in line with an underlying educational learning philosophy. They can align with a child's individual education and/or behaviour plan and be designed to support the achievement of specific objectives. For these reasons, the deployment of practitioner-developed AT solutions is appealing. Existing, widely used productivity software provides the means to produce such solutions. Once again, UDL or other guidelines may be used to guide the design of these AT experiences to ensure that are readily accessible and usable by children with special needs.

When incorporating AT within ECEC settings, social validity is important to consider. In this context, social validity rests on an assessment of the social significance of goals and the appropriateness of the AT activity, and the social importance of the outcomes as assessed by those end users (Wolf, 1978[90]). Inclusive teaching practice considers social validity in terms of the extent to which an AT solution is perceived by the children who use it to be socially valid and "normal" (Parette and Scherer, 2004[91]). There may be instances where children with special needs feel that using assistive technologies increases the visibility of their differences, and this may make them reluctant users. Social acceptability may be better achieved through widely available hardware (e.g. tablet devices) and software (e.g. games, e-books) rather than through bespoke or highly technical solutions. In addition, the use of an AT solution by all children in a classroom increases its acceptability and may result in children with special needs feeling less visible (or different) as they engage with the technology. Well-designed AT applications may support a broad range of children and therefore be of value for typically developing children alongside those at risk of learning difficulties (Case Study 2).

However, decisions on the use of AT are complex and the professionals involved need to be sensitive to the needs of the child, parental perspectives and the context in which the AT experience is deployed. Social validity is also impacted by educator views and beliefs about the extent to which AT achieves goals beyond those that might be realised through more traditional methods. Once again, this points to the importance of appropriate training and support for educators that identifies guidelines on effective AT use, and criteria for selecting appropriate solutions. In addition, ensuring that technological features such as interactivity, adaptability and personalisation *add value* to an experience designed for children with special needs is critically important. The following section discusses this point in further detail.

4. Adaptability and personalisation

Good technology design is underpinned by interactivity that encourages independent action and provides clear and useful feedback. In the context of AT, provision needs to be made for children's varied skill and ability levels to allow for independent and autonomous engagement in activities. The dynamic capabilities of digital technology provide the potential to produce experiences that are flexible in terms of:

- choices available
- action/input mechanisms (e.g. voice, touch, mouse)
- representation of information
- form of feedback (e.g. visual, audio)
- outcomes from actions.

Across the archive, there were examples of effective use of digital interactivity to provide this kind of flexibility and therefore cater for a broad spectrum of young children. In particular, the use of multimedia information representations, via text, audio, images, video and animations, was effective in supporting accessibility for children with special needs. These interactive representations allow learners to readily act upon them and experience the consequences of their actions. Each of the three case studies demonstrates the effectiveness of interactive elements in terms of choice of activity (Case Study 2), multimedia representations (Case Study 1, Case Study 2), independently activated experiences (Case Study 1, Case Study 2), replayability (Case Study 2), and real-time feedback (Case Study 2, Case Study 3). Given the potential overhead of using AT in terms of educator professional development and technology costs, AT should be assessed in terms of the value that it adds *above* what can be provided through traditional teaching resources. Important considerations for educators include the extent to which it facilitates non-teacher-directed interaction exposes educational concepts in new, different and engaging ways, offers opportunities to independently practice and repeat skills, provides useful, informative and age-appropriate feedback, and supports positive interactions with others.

There is clear evidence that bespoke programmes that meet personalised needs lead to positive outcomes. The review demonstrates the value of AT when designed, tailored and implemented to support the needs and interests of a child or group of children but within the context of a greater professional purpose. In addition, Case Study 3 demonstrates the value of adaptable and personalised professional development for educators of children with special needs. Our review demonstrates the importance of collaboration with others in the implementation of bespoke interventions. Strong partnerships are important. Those who work alongside the child(ren) (including as examples, families, educators, allied health providers and technology designers) are best positioned to inform interventions that meet the targeted need but also respond to individual children, within their unique contexts, while also making the most of the affordances the technology offers. The interaction between an individual and their surroundings is complex. The actions, interactions and experiences of all stakeholders matter for the uptake and sustained use of AT.

5. Limitations of the review

There are a number of limitations identified during the review process that need to be recognised. The first relates to the nature of the review and the focus on children's use of assistive technologies in ECEC. The nature of the review's exclusion criteria resulted in papers that were solely focused on teachers' perspectives, expert input or policy implications we not included in our archive. While this decision ensured that the review focused on children's interactions with AT and the associated outcome, it limits the ability to provide insight into teacher perspectives. While the review presents policy and practice recommendations, these emerge from the child-oriented approach taken, rather than from research that focuses specifically on ECEC policy in this area.

A second limitation is associated with the way research is being conducted in the field. Most of the papers reviewed describe small-scale research projects that involve a small number of children with special needs. While results are promising, in many instances important findings are not explored further through a larger programme of research. This issue is not unique to this field and reflects the nature of research funding that is typically short in duration and tied to specific research questions and a defined programme of work. Small participant numbers reflect the importance of contextualised research in this field that employs mixed methods including observations, one-on-one interventions and single-subject experimental design. While such research allows for detailed analysis of the "what", "why" and "how" of children's interactions with AT, generalisability is difficult and conclusions for a broader population of children with special needs are not possible.

A third limitation identified is the lack of translation activity occurring in this research area. The research being undertaken is extremely valuable, but a lack of connection to governance bodies, industry partners, education bodies and allied health results in limited end-user uptake. Research is driven by committed individuals or small groups of researchers, who, understandably, do not have a comprehensive view of the broader issues of delivery into ECEC and typically have no systematic way to connect with ECEC policy and practice in this area.

Recommendations for future directions

The following recommendations draw across our analysis of the archive to identify key priorities for the use of AT for children with special needs in ECEC.

1. A shared understanding of the role of ATs with children with special needs

Children, families, ECEC professionals, and allied health and technology designers need a shared understanding and the role and purpose of AT to support young children with special needs. Opportunities for social interaction, collaboration, problem solving, and skill development are essential in all early childhood settings and an AT resource may enable and support children in one or more ways. How the community around the child with special needs work together to develop shared understandings remains unclear. The following points provide recommended actions to achieve this shared understanding:

- *ECEC leaders and policy makers*: There is a need for curriculum and policy to recognise and articulate the value of AT in learning environments, creating clear strategic action plans aligned with operational support. This strategic planning should involve consultation with key stakeholders including families, ECEC staff, allied health providers and research organisations.
- *Technology developers*: There is a responsibility for designers of AT to ensure the technology meets the required needs of children with special needs, and that they describe the AT in language that is aligned with the pedagogical approach and learning/support outcomes (e.g. within user guides). AT design should include in-built flexibility for educators to tailor the resource and developers should take responsibility for articulating within user guides the way that adaptations modify AT interactions.
- *Educators*: Working within a clear policy and practice framework, with technology that has its purpose clearly articulated, educators can be empowered to use AT. This empowerment should be amplified through access to and participation within communities of practice where educators share examples of best practices to develop knowledge and ways of operating with, making decisions about and sharing expertise about AT.
- *Researchers*: ECEC policy setting should consider the role of research in supporting the use of AT for children with special needs. In such an environment, researchers should be encouraged to engage in communities of practice and provided with opportunities to share their knowledge and understanding in public lectures and other fora.

2. Better integration of ATs within ECEC environments

To support AT implementation there is a need to establish a clear purpose and intentionality for its use alongside routines and structures within specific early education and care contexts. More needs to be done to identify ways in which AT implementation is complementary to other valuable interactions and processes in ECEC settings to support children’s play, communication, learning and development. Understanding guiding curriculum frameworks, policy recommendations and expectations of governing bodies will empower educators to identify authentic opportunities for AT integration. This then also requires that the design of learning spaces is appropriate for AT use, with balance of both time and opportunity for digital and non-digital experiences.

Clarity around the connections between AT and the learning environment will also support children's self-regulation when using AT as use is not incidental, but instead is closely connected to established routines, structures and pedagogical intent. Reflective practices from educators both in-action (e.g. during implementation) and on-action (e.g. post implementation) will develop critical and informed understandings to generate insights into necessary knowledge, skills and approaches for AT integration. The archive shows there is power in the modification of commonly accessed technologies for the specific needs of children; however, this requires access to and knowledge of these technologies and time for educators to personalise AT. The archive reveals educators must have the training and adequate human resources (support staff) to support the implementation of AT in their learning environments. Funding initiatives that enable both technological design (AT solutions to meet needs) and human resources (time to tailor AT appropriately and integrate into learning environments with required support staff) are essential.

3. Professional learning for ECEC staff to enable digital pedagogies

The archive mostly reports data focused on children and their experiences with AT. While there is some focus on ECEC staff, there needs to be a greater emphasis on the importance of identifying and responding to professional learning needs and then providing appropriate opportunities for educators. Opportunities for professional learning for educators are essential. While it would be ideal for all educators to participate in AT professional learning, the reality is there are some who need it more than others due to the specific needs of children within their professional contexts and professional roles.

We argue all educators should be exposed to basic professional learning on AT to broadly understand what is available, with more nuanced training available to those with specialised roles and/or those who work with children with identified special needs. Reputable and evidence-informed advice for the development and selection of digital content, devices and associated software that is connected to the developmental needs of children will inform those who make decisions about what technologies are used with, by and for young children with special education needs.

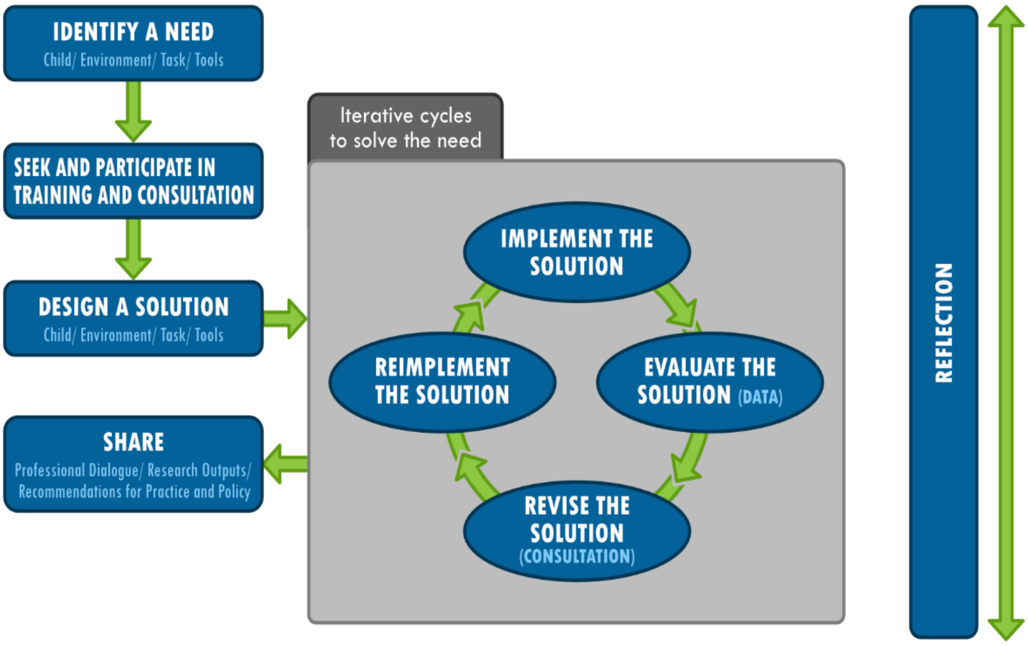
Professional learning opportunities should be tailored to begin at the point of need (i.e. the child) to inform subsequent possibilities within the learning environment and their subsequent selection and use of AT. Beginning with an identified need and working through a process to identify and/or design a solution involves more than just upskilling educators in connection with specific AT. We argue for a process where educators implement, evaluate, revise and reimplement through iterative cycles to not only build knowledge but to also empowers educators to activate their pedagogical expertise to make decisions. Opportunities to reflect throughout this process and share with others (educators and key stakeholders involved with the children) establish and build communities of practice focused on shared interests, strategies and practices to build knowledge and enable positive learning trajectories for children with special education needs.

Figure 2 synthesises key points from recommendations 1, 2 and 3 into a model for AT use integration within an ECEC setting. It embeds considerations of the child, environment, task and tools at key points in process of assistive technology integration in ECEC.

4. Looking to reported interventions to inform larger research agenda and subsequent policy

Many of the papers in our review profile interventions that while complex, are small in scale. While these showcase positive findings and benefits to their participants, there is unrealised potential about what the findings might mean on a broader scale. As highlighted through the lessons learned in case studies, and the discussion of findings, many research outcomes have implications for ECEC practice and policy. Despite these findings, significant questions remain. For example, the review recognises the importance of both bespoke AT support for individuals and well-design AT that can be utilised at scale (e.g. by a whole class of children). However, how these findings lead to informed decision making about AT use in a particular ECEC setting remains unclear. Case Studies 1 and 3 identify the importance of expert interaction and training, but the way in which this level of expertise can be embedded within ECEC in a viable and sustainable way remains an open question. Case Study 2 demonstrates the importance of knowledge and expertise that emerges from research (e.g. choosing quality AT resources) being translated into information that can be accessed, interpreted and applied by ECEC staff and policy makers. These examples demonstrate the need for additional funding opportunities to enable research collaborations to look across methodologies and findings from smaller studies, while also enabling larger-scale research projects to further inform the field. It is through strategic and focused research efforts that AT innovations will gain the profile and momentum needed to adequately inform the field. Research at this scale needs to involve external stakeholders from the community, education, government, industry and allied health.

Figure 2. Recommended model for assistive technology integration in ECEC settings



Source: Authors' elaboration.

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