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Professional development for digital competencies in early childhood education and care: A systematic review

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Abstract

Digitalisation places new demands on the early childhood education and care (ECEC) workforce to navigate the care and well-being of children in the digital age. This literature review examines frameworks for digital competencies (DC) in education, with a focus on ECEC, as well as variation in DC requirements for ECEC staff with different responsibilities. It explores strategies for a successful integration of DC in ECEC workforce development programmes. The review shows there has been limited research and policy support regarding the development of DC in ECEC and discusses the importance for the ECEC workforce to understand how digital technologies may be incorporated to their work, encompassing both technical aspects and responsible use, as well as the social and collaborative dimensions of professional development in this area. The review examines also how attitudes towards technology use with young children condition skills development in the sector.

Abbreviations and acronyms

AI	Artificial intelligence
AR	Augmented reality
BECERA	British Early Childhood Research Association
BERA	British Education Research Association
CT	Computational thinking
DC	Digital competencies
DCA	Digital Child Association
DT	Digital technology
ECA	Early Childhood Australia
ECEC	Early childhood education and care
EECERA	European Early Childhood Education Research Association
EERA	European Education Research Association
ICT	Information and communication technology
IoT	Internet of Things
IoToys	Internet of Toys
ISTE	International Society for Technology in Education
LMS	Learning management system
OECD	Organisation for Economic Co-operation and Development
OMEP	World Organisation for Early Childhood Education
PD	Professional development
PK	Pedagogical knowledge
RQ	Research question
SAMR	Substitution, Augmentation, Modification, Redefinition
SSCI	Social Science Citation Index
TK	Technological knowledge
TPACK	Technological pedagogical and content knowledge
TPK	Teachers' technological pedagogical knowledge
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
VR	Virtual reality

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Introduction

This systematic literature review focuses on early childhood education and care (ECEC) workforce development in terms of the digital competencies (DCs) needed to respond to the opportunities and challenges of digitalisation. Workforce development, including the initial education that members of the ECEC workforce are required to complete, their continuing professional development (PD), and the working conditions of staff working directly with young children, provide foundations for quality in ECEC (OECD, 2022[1]). A policy focus and ongoing processes to strengthen educators in different areas of their pedagogical and other tasks are important factors to promote quality in ECEC (OECD, 2022[2]).

The digital revolution and the need for 21st century skills highlight an ongoing discussion about ways in which ECEC professionals around the globe can address these needs in their pedagogical and everyday practices while working with children, families, relevant leaders and external stakeholders (WEF, 2016[3]). The critical components of the 21st century skills framework, which includes collaboration, communication, critical thinking and problem solving, capitalise on teachers' appropriate use of technology and hold enormous promise to help foster these critical skills in young children (Erstad, 2010[4]; Janssen et al., 2013[5]; Ng, 2012[6]; Trilling and Fadel, 2009[7]). The integration of digital technologies (DTs) in ECEC has posed challenges and dilemmas for educators, parents and children (e.g. Fotakopoulou et al. (2020[8]); Kewalramani and Havu-Nuutinen (2019[9]); Palaiologou (2016[10])). On the one hand, there is an emphasis on the integration of technology as a play-based manipulative to tune into children's learning and cognitive engagement (Arnott, Palaiologou and Gray, 2018[11]; Fleer, 2019[12]; Kewalramani and Havu-Nuutinen, 2019[9]; Marsh et al., 2019[13]; Sullivan and Bers, 2016[14]; Yelland, 2018[15]). Conversely, contemporary debates include issues like screen time and the effects on development for very young children and their well-being (Ahearne et al., 2016[16]; Lauricella, Wartella and Rideout, 2015[17]; Burns and Gottschalk, 2019[18]).

Thus, the scope of this literature review includes studies that provide the ECEC sector to firstly understand the need for developing individual DC and, secondly, to engage in critical discussions of the strengths and challenges in doing so. The literature review draws upon studies in international peer-reviewed journals and reports written for governmental or other funding agencies published for the most part between 2010 and 2022. Relevant working papers and other publications of appropriate quality and interest (e.g. peer-reviewed conference proceedings) are also included. An effort was made to include examples from a broad range of countries to be as representative as possible. Moreover, findings and areas where research is inconclusive or where more data is needed are also discussed. Due to the limited research for children under six years of age in some fields, findings from aligned levels of education, such as primary education, are drawn upon when appropriate and synthesised to suit the needs of ECEC educator's (both in-service and pre-service) professional development for DC. The rationale of this review has considered the peculiarities of the ECEC sector. In many countries ECEC is split between childcare and education. As a result, PD programmes for the ECEC workforce differ greatly among as well as within countries.

The literature review examines how PD occurs at pre-service and in-service ECEC settings and focuses on the following research questions (RQs):

1. What are the major DC frameworks for educators, specifically for those in ECEC, and the underlying theoretical models for these frameworks?
2. How are DC frameworks and/or digital dimensions of ECEC curricula reflected in workforce development programmes, both pre-service and in-service, across countries?

3. How may DC vary among ECEC staff working with young children in different age groups (e.g. 0-2; 3-6), and across the range of work processes in ECEC settings (e.g. pedagogical work; interactions with families; professional collaboration)?
4. What examples exist across countries of effective PD programmes in promoting DC for ECEC educators? What are the key features the define the quality of such PD programmes, and what opportunities exist for enhance the quality of training through the use of digital tools?

The review is organised into five sections. Section 2 provides an overview of key definitions in relation to technology and digital competencies. Section 3 describes the methodology adopted for the literature review. Section 4 presents the main findings following the research questions and themes that emerged during the analysis. Section 5 brings together the conclusions of the review and discusses recommendations and limitations.

Key technology-related definitions

This section aims to provide key definitions of the terms that will be used in this literature review.

Initially, when technologies developed and became more affordable and accessible across the world the term **information and communication technology (ICT)** was used. The term was widely used to describe any hardware (e.g. computers) and software use.

With the advancement of technologies and digitalisation gradually the term was replaced by the term **digital technology (DT)**. This was used as a "a collective term for all equipment that contains a computer or micro-controller and to which adults and children might have access, a list which now includes toys, games consoles, digital cameras, media players and smartphones as well as handheld, laptop or desktop computers" (Palaiologou, 2016, p. 1[19]). More recent, **haptic technology** has been introduced as part of the discussion about DT. The term is used to refer to any technology that can create an experience of touch by applying force, vibrations, or motions to the user (Biswas and Visell, 2019[20]) (see Annex A for specific definitions).

Since education started to integrate DT in the curriculum, a concept started becoming prominent in relation to the skills and knowledge that are needed in the 21st century: **digital competence (DC).** The concept is used to describe digital literacy and digital skills such as operational skills, safe and productive use of technology, information management and problem solving. In the literature (e.g. Ala-Mutka Punie and Redecker (2008[21]); Erstad (2010[4]); Ilomäki, Kantosalo and Lakkala (2011[22])) there is critique that the terms are used in a narrow way, either for example, referring only to Internet skills, touchscreen technology, or media literacy. In this review, however, we are using the definition from the European Framework for the Digital Competence of Educators: "Digital competence can be broadly defined as the confident, critical and creative use of ICT to achieve goals related to work, employability, learning, leisure, inclusion and/or participation in society" (Redecker and Punie, 2017, p. 90[23]).

Methodology

This review followed the Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA) approach for conducting transparent reports that are based on literature reviews (Page et al., 2021[24]). The review started with a broad search in university electronic catalogues as well as in reference databases (see Annex B). The main search terms included: "*pre-school, early childhood education, early years education, digital technology, professional development, digital frameworks*".

The year set for starting the search was 2000. The purpose of including publications from 2000 onwards was to enable the examination of previous conditions and understanding of the changes that occurred through time. The main literature review on the findings consists of publications from 2010 to 2022. After locating academic papers and research publications, the search focused on policy documents, reports and conference proceedings, as detailed in Annex B.

Besides publication date, four more questions guided the initial search:

1. Whether the paper was published in a peer-reviewed journal.
2. Whether it was a research-based article or a systematic literature review.
3. Whether it was referring to the education and care of children from birth to eight.
4. Whether the publication related to professional development in relation to digital technology and whether the context involved in-service ECEC educators or pre-service ECEC teacher education.

The research team consisted of academics who could search relevant literature in English, Greek and Scandinavian languages. After identifying an initial set of publications, a scanning of their titles, abstracts and methodology (where applicable) was completed. Inclusion and exclusion criteria are explained in Annex B. The research team members worked individually at first and then as a team discussed a final list of publications. Finally, the list comprised of 173 scientific articles, 27 book chapters or books and 33 reports or national plans.

In the first step of analysis, a coding scheme that comprised of the key search terms, consistent with the study's research questions was outlined. The included publications were repeatedly read by the authors to identify codes based on the coding scheme. These codes were compared and contrasted to identify themes relevant to understanding of, for example, DC frameworks, theoretical models and related teacher PD programmes and practices for both pre-service and in-service, across countries. Themes have been reported if they were observed repeatedly across the reviewed studies and were specifically linked to the study's five research questions.

Biases and other concerns were also discussed to be rigorous and to confirm that no important information was excluded. Limitations of the whole process are presented in this report to ensure transparency and validity of our findings.

Findings

The findings are presented following the research question addressed in the review.

1. Digital competence frameworks

This section explores major digital competence frameworks for educators, with a focus on those for ECEC, as well as underlying theoretical models for the development of these frameworks.

Digital competence frameworks for educators

In a digital world, understanding of DC goes beyond including technical/operational skills that are relatively less important than pedagogical competencies and knowledge for promoting safe and responsible approaches of digital technology (Ilomäki et al., 2016[25]). DC is an evolving concept related to the development of digital technology and the political aims and expectations of citizenship in a knowledge society. It is regarded as a core competence in policy papers, but in educational research it is not yet a well-researched concept. Development of DC frameworks is still considered as an abstract concept, which must include not only the understanding of social nature of knowledge constructions, but also ethical consequences of the digital practices and engagement by adult stakeholders (ECEC educators, parents/caregivers) (Lundqvist, Baker and Williams, 2008[26]). Hence, to understand and research specifically ECEC workforce DC and use of DT, there is a need to break down, for example, the components of existing DC frameworks and make a holistic meaning of DC and professional development.

The current literature review synthesis found very few DC-related frameworks/models that particularly focused on ECEC, with most focusing on primary education. In the context of ECEC, most frameworks and models are developed and applied in EU (Spain, Norway and Sweden e.g. Dardanou and Kofoed (2019[27]); Lindeman, Svensson and Enochsson (2021[28]); Novella-García and Cloquell-Lozano (2021[29]); Urrea-Solano et al. (2021[30])) and a few in Australia (e.g. Kewalramani, Palaiologou and Dardanou (2023[31]); Yelland (2017[32])). DigCompEdu and Technological Pedagogical and Content Knowledge (TPACK) are the most frequently used frameworks for studying and assessing DC of educators in all professional areas, including ECEC. Many studies affirmed the importance of tertiary education in ECEC in improving pre-service educators' DC (Luo, Berson and Berson, 2021[33]; Luo et al., 2021[34]; Urrea-Solano et al., 2021[30]). However, understandings and application of teachers' DC development still plays a less important role In the training of pre-service educators, although its significance has been widely recognised (Guillén-Gámez and Mayorga-Fernández, 2020[35]; Galindo-Domínguez and Bezanilla, 2021[36]; Masoumi, 2021[37]). In addition, more studies focus on the DC of pre-service teachers than in-service teachers. For example, in the Norwegian context, Godhe (2019[38]) suggested that one characteristic of Nordic curricula compared to other countries, concerning DC of both pre-service and in-service teachers, is the emphasis on societal issues and a critical and ethical approach towards understanding the application of DT when it comes to the point of DC of the ECEC workforce. Erstad, Kjällander and Jarvela (2021[39]) posit that in Sweden, Norway and Finland, more and more attention is drawn towards pre-schoolers usage of DT, both in curriculum development for pre-schools and research, for example computational thinking. This expectation of children's acquisition of DC has implication on educators' DC (e.g. TPACK) and is becoming more prominent in educational policy.

In a review conducted by Ilomäki et al. (2016[25]), the authors analysed 76 educational research articles in which DC was described by different terms. The study found that DC consists of a variety of skills and competencies, and its scope is wide, as is its background: from media studies and computer science to library and literacy studies. DC was found to be described in conjunction and contexts related to digital technology related skills and competencies of young children; the most often used terms were ‘digital literacy’, ‘’new literacies’, ‘multiliteracy’ and ‘media literacy’, each with somewhat different focus. The study recommended a comprehensive DC framework that can be used for research being conducted about generating new knowledge about developing ECEC professional’s DC development. While it is imperative to build children’s DC, policy and curricula frameworks should firstly focus on the ECEC workforce DC development (Dardanou and Kofoed, 2019[27]; Lindeman, Svensson and Enochsson, 2021[28]). For example, The Ministry of Education in China (2014[40]) suggests ECEC educators’ DC should include the capability to use technologies to improve learning outcomes as well as design instruction to accommodate children’s new learning styles. To use technology, educators’ DC needs to be developed professionally through modelling and mentorship of educational pedagogy (Lakkala and Ilomäki, 2015[41]) and early childhood educators require an enhanced understanding of the skills, dispositions, and knowledge for teaching–learning contexts where technologies as a medium for developing children’s communication skills are increasingly pivotal (Dardanou, Palaiologou and Kewalramani, 2023[42]; Kewalramani et al., 2020[43]; Kewalramani, Kidman and Palaiologou, 2021[44]; Palaiologou, Kewalramani and Dardanou, 2021[45]). Ilomäki et al.’s (2016[25]) framework suggests that teacher’s DC consists of (1) technical competence, (2) the ability to use DT in a meaningful way for working, studying and in everyday life, (3) the ability to evaluate DT critically, and (4) motivation to participate and commit in the digital culture. Very few studies to date have researched ECEC workforce DC for pedagogical purposes, including the poor integration of DC development of pre-service teachers within teacher education programmes and applicable DC frameworks (Erstad, Kjällander and Jarvela, 2021[39]; Tømte, 2015[46]). In a study conducted by Luo, Berson and Berson (2021[33]) focusing on Chinese projects, showed that the training programmes focused more on technical skills rather than the pedagogy. Moreover, the issues around the changing landscape of available technologies deterred early childhood teachers from using technologies for teaching and learning purposes.

Research is ongoing with respect to understanding of success and barriers on the applicability of workforce DC for different purposes and within ECEC contexts (Mertala, 2021[47]; Parette, Quesenberry and Blum, 2010[48]; Rosen and Jaruszewicz, 2009[49]). Recent studies such as Wang, Lavonen and Tirri’s (2018[50]) is still showing that the national curricula frameworks such as those seen in China and Finland, do not provide a detailed list of requirements for specific digital contents, with even definitions of the learning contents of essential digital phenomena remaining minimal. The definitions of aims, content and practical guidelines in curricula should be clear for a broad conception of ECEC educators’ DC (Ilomäki et al., 2016[25]).

One such seminal framework was the DigComp framework which was a comprehensive DC framework proposed by the European Commission (Ferrari, 2012[51]). The framework suggested five areas of DC (Information, Communication, Content Creation, Safety and Problem Solving) across three proficiency levels (Foundation, Intermediate, Advanced). Additionally, more recently, the DigCompEdu – European framework for DC of education professionals (Redecker and Punie, 2017[23]) – adapted from DigComp framework – highlights what it means for educators to be digitally competent. For each of the 22 elementary competencies, the competence descriptor is complemented by a list of typical activities. For example, in the areas of teaching and learning, assessment and empowering learners, a digitally competent ECEC educator would create and share digital resources, plan and manage the use of Dt in teaching and learning, including assessment practices. While doing so, educators would demonstrate inclusion, personalisation, and children’s active engagement. These activities would form the core of an ECEC educator’s everyday pedagogical practices where they incorporate DT as part of their pedagogical repertoire.

In addition, within the DigCompEdu framework (Redecker and Punie, 2017[23]), a progression model along six levels are proposed (professional engagement, digital resources, assessment teaching and learning, facilitating learners’ digital competence), for which a rubric with proficiency statements for self-assessment is supplied. According to this approach educators need to have proficiency awareness in relation to their professional, pedagogical and learner’s competencies.

These stages and the logic of their progression are inspired by Bloom’s Revised Taxonomy (Anderson and Krathwohl, 2001[52]). It is widely accepted that this taxonomy explains the subsequent cognitive stages of any learning progress well, from “Remembering” and “Understanding”, to “Applying” and “Analysing”, and finally to “Evaluating” and

"Creating". Similarly, in the first two stages of DigCompEdu, Newcomer (A1) and Explorer (A2), an ECEC educator might assimilate new information and develop basic digital practices; at the following two stages, Integrator (B1) and Expert (B2) The ECEC workforce members, apply, further expand and reflect on their digitally constructed pedagogical practices; and lastly, at the highest stages, Leader (C1) and Pioneer (C2), ECEC educators pass on their knowledge, critique existing practice and develop new practices. These six levels can form a continuum of sustainable digital integration of technologies and pedagogically sound practices applicable to early childhood classrooms.

In the Finnish ECEC curricula framework (FNAE, 2018[53]), teachers' digital competencies can be seen as developing children's transversal competencies, where educators incorporate learning activities involving children's multiliteracy. Children are encouraged to explore, use and produce messages in different contexts and environments, including digital ones. Another framework suggested by the Norwegian Ministry of Education and Research (Kelentrić, Helland and Arstorp, 2017[54]) is the Professional Digital Competence Framework for Teachers. The Norwegian Centre for ICT in Education introduced the concept of professional DC in 2012, in connection with suggestions for providing a new framework for teacher education with respect to developing educators' DC skills and knowledge, specifically focusing on pedagogy and progressing towards becoming a digitally competent leader. The centre viewed this as critical, to highlight the key role the teaching profession plays in promoting digitalisation in schools, and the development of DC pupils. The concept of DC is now commonly used in Norway, in both research environments and official steering documents. The Norwegian framework for professional DC promotes the role of the teacher to be capable of developing pupil'' basic skills and specialised knowledge via interactions and communication. To do so, educators must develop their own professional DC during their initial teacher education, and later, through continuing professional education and development, during their teaching career. The framework for teachers has two aims: one centres on professional development, the other around the actual practice of the profession. If the teachers of the future are to be capable of developing children's DC, in line with the stipulated obligatory guidelines and requirements, professional DC must be regarded as an integral part of teacher competence and the teaching profession and emphasised in teacher education.

The framework promotes all the areas of digital competence as equally important, but it is the sum of the competence areas that makes up a professional, digitally competent educator. Of significance to ECEC, the role of a DC educator is being able to understand the influence of digital developments on children's childhood environment, culture, development and identity. The educator understands their own role, and the role of ECEC settings, in bridging the digital divide, and can help all children orient themselves and be active participants and contributors in a global, digital and democratic society.

Moreover, during the COVID-19 pandemic, the impact of the digital divide was particularly damaging for the most vulnerable groups, who experienced serious difficulties in accessing DT and related tools (UN, 2020[55]). Hence, DC training for sustainable use of technologies has become a key element for both educators and children. According to Sánchez-Carracedo et al. (2021[56]), this element is specifically related to four domains for ECEC educators in Spain: (1) the critical contextualisation of knowledge and its link to social, economic, and environmental problems; (2) the sustainable use of technological resources and the prevention of their negative social, environmental and economic effects; (3) participation in collaborative processes that favour digital sustainability; and (4) the use of ethical principles related to personal and professional behaviour.

Comparing the DC frameworks reviewed in this section, it seems sustainable and ethically informed use of technological resources, planning and assessing for and incorporating pedagogically sound digital tools, collaborating and seeking mentoring and active engagement in research-informed PD opportunities remain the cornerstone for an evolving ECEC educators who are DC. Additional skills a DC ECEC educator might require are critical thinking and ethically sound choice-making of digital tools, problem solving, communication and collaboration, interwoven with reflective practice.

Theoretical models for the development of digital competencies

Discourses about DC and digital literacy tend to focus on traditional theoretical perspectives that involve the decoding and encoding of the meaning of DC and the related dimensions. Multimodality is one such theoretical perspective in relation to the understanding of DC, which is the set of knowledge, skills and attitudes needed today for an ECEC educator to be functional in a multimodal (multiple modes of meaning making) environment (Kress, 2010). Besides focusing on the teaching and learning of the technical requirements needed while using DT, dimensions of a DC ECEC educator involve the procurement of a new set of skills, knowledge and attitudes, involving multiple literacies, which are often left aside in educator PD and assessment discourses. Multimodality perspectives look beyond written language and allow the examination of multiple modes of communication that underpins ECEC workforce practice (mixed and remixed images, writing, layout, sound, gesture, speech, and 3D objects) for meaning making and enabling DC (Kress, 2010[57]). Applying the theory of multimodality provides the framework necessary for understanding the attempt to bring all modes of meaning making together under one unified theoretical roof for educator DC development. Each mode has its own affordances and limitations which are shaped by both their own nature (materiality) and by the social experiences of the communicator with that given mode (their communicative competence) (Kress, 2010[57]). For example, Ling et al. (2021[58]) suggest teachers critically understand the multimodal nature of technologies as affordances to promote children's communication and meaning making of everyday world. Such an understanding aligns with Ilomäki et al.'s (2016[25]) framework where ECEC educators can use DT in a meaningful way for teaching and learning and the ability to evaluate DT critically for pedagogical purposes. In line with the DigCompEdu framework (Redecker and Punie, 2017[23]), a DC ECEC educator, whether a Newcomer and/or an Explorer, can critically assimilate new information and develop basic digital practices before becoming an Integrator and Evaluator (rather than the Expert) for incorporating DT as a multimodal learning tool in ECEC learning environments. However, it is important as the first step for the ECEC workforce to embrace the multimodal nature of technologies to enable their own meaning making of the affordances offered by technologies and integration for pedagogical purposes.

Competence acquisition in a digital era can also be defined as a mindset, enabling the ECEC educator to adapt to the new requirements and dynamic nature of evolving technologies (Koehler, Mishra and Cain, 2013[59]; Lindeman, Svensson and Enochsson, 2021[28]). In addition, being "fluent" or "native-like" with technologies only happens when DC acquisition is embedded in a social practice, which entails certain ways of holding certain beliefs and values about them, and socially interact with technologies (Casillas Martín, Cabezas González and García Peñalvo, 2019[60]). In other words, technologies need to be appropriated by educators in pedagogically sound ways – one important skill set recommended in the DigCompEdu framework (Redecker and Punie, 2017[23]). ECEC workforce appropriation might mean for example, educators deploy DT in specific ways and interact with technologies (and therefore it requires specific attitudes), of understanding them (and therefore holding specific technological and pedagogical knowledge), of being able to use them (and therefore having specific skills) (Guillén-Gámez and Mayorga-Fernández, 2020[35]). Such appropriation of educators interacting and integrating technologies in pedagogically sound ways is also significant in initial teacher education within early childhood courses and programmes (Krumsvik, 2014[61]; Luo, Berson and Berson, 2021[33]; Luo et al., 2021[34]). In practice, adoption of DT and systematic training and mentoring is urgently needed for ECEC workforce development. To do so, the theoretical application of multimodality is one way of understanding the benefits as to why ECEC educators should integrate technologies in their early childhood pedagogy – another important factor that can lead to teachers' increased confidence and motivation (Ling et al., 2021[58]).

Two conceptual frameworks have been highlighted in literature as frequently used for informing the design of educator's digital competence development and programmes and have been well-supported by empirical research. They are Mishra and Koehler's (2006[62]) TPACK framework (e.g. Dardanou and Kofoed (2019[27]); Kewalramani and Havu-Nuutinen (2019[9]); Masoumi (2021[37]); Park and Hargis (2018[63]); Tan et al. (2019[64]); Voogt and McKenney (2017[65]) and Puentedura's (2006[66]) SAMR model (e.g. Aldosemani (2019[67]); Baz, Balçıkanlı and Cephe (2018[68])). However, not many studies are in the context of ECEC.

A broader and more inclusive framework that goes towards addressing the importance of teachers' technological and pedagogical knowledge and skills, is Mishra and Koehler's (2006[62]) TPACK model which builds on the earlier work of Shulman (1986[69]), "to explain how teachers' understanding of educational technologies and pedagogical content knowledge (PCK) interact with one another to produce effective teaching with technology" (Koehler, Mishra and Cain, 2013, p. 14[59]). TPACK does not represent a hierarchy or staged progression, but rather presents a holistic model that theorises the relationship between, and contribution of, technological, pedagogical and content knowledge to effective curriculum learning-focused technology use. TPACK merges each element into a central core that blends deep and robust discipline conceptual knowledge (CK) with an understanding of the potential of, and capacity to use technology (TCK) to enhance learning, through supportive pedagogies (TPK) that acknowledge students' prior understandings and learning needs. The success of TPACK relies on the capabilities of educators within each domain, and their capacity for flexibility, willingness to update, and readiness to explore how the domains interrelate to support effective technology use in a range of different situations. While TPACK acknowledges the integrative relationship between conceptual content knowledge and pedagogy and technology, within teacher education programmes this relationship is seldom reflected in initial teacher education for early childhood course design and teaching practices (Ndongfack, 2015[70]). Studies have indicated the need to also consider the affective elements (confidence, motivation, characteristics of the ECEC context) for building ECEC educators' TPACK, where A stands for affective (Park and Hargis, 2018[63]).

One ECEC-related study (Kewalramani and Havu-Nuutinen, 2019[9]) investigated the complex interplay and interaction between pre-school educators' pedagogical knowledge (PK) and technological knowledge (TK) when teaching science concepts. Educators' Technological Pedagogical Knowledge (TPK) is considered the basis of effective teaching with the integration of technology, especially in the context of play-based pedagogical practices in pre-school settings. Chuang and Ho (2011, pp. 101-102[71]) define TPK as "the knowledge of how technology can create new representations for specific content and can impact the practices and knowledge of a given discipline". The authors suggest that when educators understand, by utilising a specific technology as a teaching and learning tool, they can change the way in which learners practice and comprehend concepts in a specific content area. This includes the knowledge of pedagogical affordances and constraints of different technological tools. This study considered TPK as a sub-strand of TPACK, where technology can be integrated by educators as a useful pedagogical tool for promoting children's science learning and inquiry, when its use is well-rationalised. Although educators' development begins with being equipped with professional knowledge about the scientific content to be taught, pre-school educators' TPK is equally important. For example, TPACK for pre-school educators may include knowledge regarding representations of abstract (non-observable) scientific concepts using virtual reality (VR) apps, for example, where the educator sparks children's design thinking process for physical scientific concepts by use of virtual reality simulations and encouragement of peer-peer interactions. Such an example of using age-appropriate ways of integrating technologies requires educators' own pedagogical reasoning of integration of ICT tools (Chuang and Ho, 2011[71]). To understand how pre-school educators integrate technology in their pedagogical practices to promote scientific inquiry, Kewalramani and Havu-Nuutinen (2019[9]) developed an initial conceptual framework which is predicated on the TPACK concepts (Mishra and Koehler, 2006[62]). Since the studied knowledge primarily focuses on educators' effective pedagogical practices in a technology-enhanced learning environment, only the TPACK sub-category elements of TPK (TK and PK) were included in the conceptual framework.

Another technology framework is SAMR (Substitution, Augmentation, Modification, Redefinition). It is essentially a descriptive framework that maps different educational uses of technology hierarchically against levels or stages – progressing from Substitution ('doing digitally' what has traditionally been carried out using conventional resources) through to Redefinition (curriculum, pedagogy and practice reconceptualised through DT). SAMR has been widely adopted by teacher educators and schools as a pragmatic guide for signposting ICT development progress. According to Puentedura (2006[66]), at the Redefinition stage, the highest level, educators make use of technology as tools that enable creation of new tasks that were previously inconceivable tasks. Such tasks align with the exercise of higher order thinking capabilities such as analysing, evaluating and creating. At the Substitution stage the lowest level, "technology acts as a direct tool substitute with no functional change" which Puentedura (2006[66]) aligns with lower order thinking capabilities, such as understanding and remembering. The Augmentation and Modification stages represent intermediate steps between Substitution and Redefinition, describing increasing complexity and sophistication in using technology to facilitate changes to learning design and pedagogy, progressively supporting greater levels of curriculum innovation.

The literature review showed a limited number of studies have applied SAMR model concepts, primarily because of lack of appropriate confidence in technical skills and absence of pedagogical reasoning behind the value of integrating technologies in ECEC (Schriever, 2021[72]). Nevertheless, the SAMR framework may be useful for pre-service and practicing ECEC educators by providing descriptive, practical and easy to understand 'aim points' towards which to evolve their practice. The model does not provide concrete illustrations of practices that might represent each stage, or ways of transitioning through the stage – nor does it explicitly account for supporting necessary pedagogical, technological and learning design changes. Although appealing possibly because of its simplicity, SAMR focuses solely on describing levels of discipline-based technology integration (e.g. literacy/numeracy teaching and learning practices in ECEC), reflecting a narrow interpretation of the understandings teacher education students need for the more holistic and comprehensive capability set required by an expanded view of DC.

Considering the theoretical models so far in this section, it is evident that there is a need for the development of a conceptual model specifically made for the ECEC workforce. Such theoretical models should primarily be in alignment with ECEC pedagogical principles (e.g. child-centred, play-based learning) and should also account not only for the digital skills and integration in ECEC settings, but also the multimodal affordances offered by DT. More studies to investigate the usefulness and application of the existing frameworks and the elements for educators DC development in ECEC settings would also be the next step in early childhood digital education research.

2. Digital competencies in professional development programmes in early childhood education and care

This section explores the integration of digital competence frameworks and/or digital dimensions of early years curricula into ECEC workforce development programmes, both pre-service and in-service.

Digital dimensions of frameworks for early childhood education and care workforce development

The debates around ECEC educators' DC and digital literacy development are not new. One of the first attempts to support digital literacy and competence was suggested by the European Digital Literacy (DigEuLit) (Martin, 2006[73]) framework which proposed a series of questions that teachers can ask students for self-assessment that furthers teacher planning. The digital dimensions within the three level model were: Level 1: Digital Competence (general skills and attitudes towards the use of DT, the components may be mastered at different levels of expertise, varying from basic skills to more analytical competence); Level 2: Digital Usage (the application of DC within specific professional or domain contexts); Level 3: Digital Transformation (achieved when digital usage enables innovation and creativity and stimulates significant change at individual or organisational level). Although Newman (2008[74]) proposed looking at digital literacy as the use of critical thinking skills in the context of children's technology use, digital literacy can be understood more holistically, as requiring both technical skills and critical thinking skills for both children's and educators' DC development.

Further, in 2012, Ferrari also suggested that DC be closely related to other types of digital dimensions such as digital literacy. The current literature review demonstrated that DC frameworks and models are mostly used as assessment tools to study pre-service and in-service educator's DC in ECEC. Both frameworks and models contribute to digital reform in teacher education for pre-service teachers and to promote PD in DT for in-service teachers. For example, in Norway (Dardanou and Kofoed, 2019[27]; Erstad, Kjällander and Jarvela, 2021[39]), digital skills and competence have been required by primary curriculum but are not clear in ECEC. In the Australian context, although ECEC curricula (such as the Early Years Learning Framework, by the Department of Education and Workplace Relations (2009[75])) promotes the engagement of children with DT, it has nothing relevant to the barriers educators must overcome (e.g. concerns, lack of DC and lack of understanding) (Schriever, 2021[72]).

Some successful application about ECEC educators extending their pedagogical repertoire by incorporating the use of iPads in their early childhood programmes can be seen in the Australian context. Yelland's (2017[32]) study incorporated the SAMR model (Puentedura, 2006[66]), where researchers and educators together with the children explored the possibilities of using the tablet in ways that would support the pre-primary educators' curriculum and pedagogical work. In thinking about this in the context of the SAMR model, the activities on the tablet were used as a direct substitute for traditional activities that had not enabled the children to come to understand the numeracy and scientific concepts in the first instance, then as augmentation for activities that were usually presented in two or three dimensions. Finally, the app made possible modifying those activities offered with multimodal ways such as sound, digital touch, taking children's learning to a new level by incorporating a new modality. This study suggests rethinking the ways in which the ECEC workforce, in partnership with children, could explore technologies which iPads use, whereby the educator offers the learning context and modality – a vital skill of a DC teacher.

Skantz Åberg et al. (2022[76]) provided an overview of how research and policy can conceptualise all educators' professional DC. The authors recommend the conceptualisation of a technological pedagogical digitally competent (TPDC) professional needs to be directed away from the strong focus on the technological competence and basic hands-on skills of individual educators to a focus on a collective responsibility and accountability for TPDC, including support from the leadership personnel. This means in the ECEC context, bringing together the micro (educator-child at the centre), meso (educators as peers, parents and leaders), exo (local community and environment, curricula and policy, research, teacher education and teacher educators), and macro (global context, organisations and policy, socio-technological changes) systems as a partnership model to conceptualise and implement support for ECEC workforce DC development process.

Strengths and limitations of existing digital competence frameworks for early childhood education and care workforce development

UNESCO's initiative Education for All prioritises inclusion and quality of DT in education (UNESCO, 2018[77]). Yet, internationally, through this literature review, it is evident that firstly there is a need for the availability of specific DC frameworks for the ECEC workforce to have ready access to, and secondly, PD opportunities to make sense of the DC framework and related curricula and policy, which is currently scarce. Further, in the early childhood education space, there is a mismatch between curriculum documents that identify digital literacy as an educational aim (e.g. Finland, Spain, Norway, Australia), and other policy documents where there is a notable absence of comment regarding the provision of ECEC educators' DC development and related professional learning opportunities (Erstad, Kjällander and Jarvela, 2021[39]; Thorpe et al., 2015[78]). Hence, more recently in the last decade, there has been development of different models for both measuring and understanding DC amongst ECEC educators (Galindo-Domínguez and Bezanilla, 2021[36]). Some international organisations such as UNESCO (2018[77]) have tried to establish a definition and criteria for educators' DC. However, the translation of DC skills into authentic practice is still under-researched, although some research is developing for the preparation of future educators (pre-service teachers).

In adapting the general European DigComp model (Ferrari, 2012[51]), many countries have developed their own frameworks to address the social needs and educational contexts and requirements for digitisation. Some recent examples are the Spanish Common Framework for Digital Teacher Competence (INTEF, 2017[79]) and the Norwegian Professional DC Framework for Teachers (Kelentrić, Helland and Arstorp, 2017[54]). Taking some of these models as a reference, particular authors have also developed their own proposals for developing educators' DC and instruments for its measurement (González-Martínez, Martí and Cervera, 2019[80]; Gutiérrez Porlán, Luis and Sánchez, 2016[81]). For example, the dimensions of a DC teacher (e.g. pre-service, in-service, teacher educator) in the INTEF framework from Spain (INTEF, 2017[79]; Galindo-Domínguez and Bezanilla, 2021, p. 264[36]) includes:

1. **Information**: This dimension, seeks to learn to identify, locate, obtain, store, organise, and analyse digital information, data and digital content, evaluating their purpose and relevance for teaching tasks.
2. **Communication**: This dimension seeks to learn to communicate in digital environments, share resources through online tools, connect and collaborate with others through digital tools, interact and participate in communities and networks; intercultural awareness.
3. **Content creation**: This dimension seeks to learn to create and edit new digital content, integrate and rework knowledge and previous content, make artistic productions, multimedia content and programming, and know how to apply intellectual property rights and licenses for use.

4. **Safety**: This dimension encompasses the protection of information and personal data, protection of digital identity, protection of digital content, security measures, and responsible and safe use of the technology.
5. **Problem solving**: This dimension seeks to learn to identify needs for the use of digital resources, make informed decisions on the most appropriate digital tools according to the purpose or need, solve conceptual problems through digital media, use technologies creatively, solve technical problems, update your own competence and that of others.

With respect to adopting the INTEF (2017[79]) framework, Galindo-Domínguez and Bezanilla (2021[36]) found the need to continue developing successful PD programmes for the development of DC of ECEC educators, especially in relation to the dimension of digital content creation. In addition, within the international literature involving educator and child as the co-learner while deploying technologies in early childhood classrooms as a learning tool, empirical studies are showing in favour of early childhood education educators and their attitude regarding the use of ICT as a tool to promote the inclusion of children with special educational needs (Casillas Martín, Cabezas González and García Peñalvo, 2019[60]; Kewalramani, Kidman and Palaiologou, 2021[44]).

In another (Swedish) study with ECEC educators, Lindeman et al. (Lindeman, Svensson and Enochsson, 2021[28]) applied the concept on 'domestication' (the extent and frequency of technology integration by an ECEC educator) as a dimension for in-service teachers' DC development. The study showed that when DT such as tablets and floor robots are used together with children and educators in a pedagogical way, for a teacher's DC to remain sustainable, educators expressed the need to increase their competence and stay updated. Several educators complained that there is no support to contact when the instruments do not work or just to ask for advice. These factors increase the risk that the domestication process slows down or reverses. Consequently, the dimension of educator's sustainable use of technologies, together with the pedagogical rationale for application of technologies, becomes an urgent area to be addressed. This can happen via continuous monitoring and ongoing support for domesticating workforce DC skills and confidence in reaching an expert level and not remain at the novice integrator level (Ng et al., n.d.[82]).

A study conducted by Romero-Tena et al. (2020[83]), also recommended the digital dimension of pedagogical knowledge of technology to know, understand, and apply its didactic and methodological use in teaching–learning processes in ECEC classrooms. However, the study reported that because the presence of technologies in most ECEC contexts is still scarce and, in most cases, those educators who venture to incorporate them use their own resources, educators need PD and initial teacher training providers should prioritise the dimension of putting the creation and adaptation of digital content more into practice. All this reaffirms the importance of and the need for university ECEC degrees to promote and offer adequate training to ensure that future ECEC educators experience initial teacher training as being sufficient to boosting their confidence to incorporate technologies (Romero-Tena et al., 2020[83]). As such, for a future ECEC workforce preparation that aims for a DC 'Newcomer and Explorer' teacher (Redecker and Punie, 2017[23]), who feels sustainably confident and motivated to use digital tools in their everyday ECEC classroom instructional practices, there is a need for ongoing professional mentoring of ECEC educators. Only then educators will learn to position themselves at an expert level and be able to progress being an 'innovator and leader', but that can happen only when they receive basic level of ICT related experiences in their pre-service training contexts.

With respect to pre-service teacher training, Falloon (2020[84]) presents a conceptual framework introducing an expanded view of educator (including pre-service teacher's) DC as teacher digital capability (TDC). It moves beyond prevailing binary DC conceptualisations of developing educators' technical skills and digital literacies, arguing instead for more holistic understandings that recognise the increasingly complex knowledge and skills educators need to be able to foster pedagogically sound digital-mediated practices. Falloon (2020[84]) suggests TDC-related frameworks should include more than a passing mention of personal dispositions/attitudes or understandings of wider issues or safety and well-being considerations, as being sole components of pre-service educator's DC. Official documents and frameworks (e.g. DigCompEdu (Redecker and Punie, 2017[23]); International Society Teacher Education Standards for Educators (ISTE, 2017[85]); ICT Competency Framework for Teachers (UNESCO, 2011[86])) tend to emphasise ICT skills, prioritising the acquisition of technical and procedural skills. On the other hand, for ECEC workforce DC development, stakeholders should consider dimensions that deliver ethical and safe choice and use of technological resources and social/collaborative elements which are important for ECEC educators to incorporate as part of sustainable critical reflective practice. Re-conceptualisation of ECEC workforce DC development frameworks should recognise the more diverse knowledge, technological and pedagogical capabilities and dispositions (e.g. critical thinking, digital judgement), needed by pre-service educators and teacher educators (Crompton, 2017[87]; Falloon, 2020[84]; Krumsvik, 2014[61]).

3. Variation in digital competencies requirements in early childhood education and care

This section explores how digital competence needs may vary among ECEC staff working with young children in different age groups (e.g. 0-2; 3-6), as well as for other types of work tasks in ECEC settings (e.g. interacting with families, professional collaboration).

There is limited research on how DC requirements might vary for different age groups. Emphasis in the literature is placed on researching whether digital play is real play (e.g. Alvestad et al. (2017[88]); Bird and Edwards (2015[89]); Edwards (2013[90]); Johnston, Hadley and Waniganayake (2020[91]); Marsh et al. (2018[92]); Palaiologou, Kewalramani and Dardanou (2021[45])) and few studies include children under the age of three (Fotakopoulou et al., 2020[8]; Gillen et al., 2018[93]; Hatzigianni and Kalaitzidis, 2018[94]; Jernes and Engelsen, 2012[95]; Lafton, 2019[96]; Ljunggren, 2016[97]; O'Connor et al., 2019[98]; O'Connor and Fotakopoulou, 2016[99]).

The following theme synthesises literature and poses implications for the need for ECEC workforce DC development for pedagogical purposes as well as facilitating communication with other stakeholders such as families and colleagues.

Pedagogical uses of digital technologies with children in different age groups

Literature highlights the disconnection between technology use of young children at home and in ECEC settings (Aldhafeeri and I., 2016[100]; Aldhafeeri, Palaiologou and Folorunsho, 2016[101]; Alvestad et al., 2017[88]; Arnott, Palaiologou and Gray, 2019[102]; 2019[103]; Aubrey and Dahl, 2014[104]; Edwards et al., 2020[105]) and stress that the integration of technology varies on teacher's knowledge and beliefs. Nevertheless, the lack of training has created tensions and confusion on how to use digital technologies in pedagogically sound ways and with what ages of children (Jack and Higgins, 2019[106]; Sulaymani, Fleer and Chapman, 2018[107]; Johnston, Hadley and Waniganayake, 2020[91]; McGlynn-Stewart et al., 2017[108]). Despite studies that show positive integration of technologies in ECEC, some studies found that educators expressed anxieties about digital technology having a negative impact on children in terms of their well-being, social, physical development and health (e.g. Vidal-Hall, Flewitt and Wyse (2020[109])). Finally, there is meaningful research that is emerging in recent years on how educators and children learn with and from technology (Chatzigeorgiadou et al., 2022[110]; Dunn et al., 2018[111]; Hatzigianni et al., 2020[112]; 2021[113]; Johnston, Highfield and Hadley, 2018[114]; Kewalramani et al., 2020[43]; Kewalramani, Palaiologou and Dardanou, 2020[115]; Kewalramani, Kidman and Palaiologou, 2021[44]; Kewalramani et al., 2021[116]).

To address the DC requirements among ECEC staff working with young children in different age groups, however, there is a necessity to examine the changing nature of technologies as this might impact the competence required to use them. Examining the literature on the use of digital technologies there are two main areas. Literature on digital technologies prior to 2005 mainly examined use of computers and cameras. Their inclusion in ECEC was seen as an "add-on" instead of looking at the potentialities of their integration and their use was dependent on teachers' pedagogical knowledge and expertise (Plowman and Stephen, 2003[117]; Stephen and Plowman, 2003[118]; Yelland and Masters, 2007[119]). For example, the inclusion of cameras for documentation purposes was widely used mainly by educators. As children were getting older (age 3-5 years), research demonstrated that children were offered opportunities to use these technologies themselves to document their experiences and learning (Aldhafeeri, Palaiologou and Folorunsho, 2016[101]; Bird and Edwards, 2015[89]; Danby et al., 2018[120]; Fleer, 2019[12]; 2020[121]; Hatzigianni and Margetts, 2012[122]; Hatzigianni et al., 2020[112]; 2021[113]).

Following the introduction of touchscreen technology and haptic technology, however, research shifted to examine the integration of these technologies in ECEC where children and educators "work together" as co-researchers (Palaiologou, Kewalramani and Dardanou, 2021[45]; Hatzigianni et al., 2018[123]; 2020[112]; Kewalramani, Palaiologou and Dardanou, 2023[31]). Research also focused on the use of technologies on more specific academic-related subjects, such as literacy, science and mathematics (Bers, 2018[124]; 2019[125]; Belo et al., 2016[126]; Burnett, 2010[127]; Chatzigeorgiadou et al., 2022[110]; Forbes et al., 2020[128]; Kucirkova et al., 2019[129]), technology and learning (Hsin, Li and Tsai, 2014[130]), technology in relation to healthy practices, relationships, pedagogy and digital play (Mantilla and Edwards, 2019[131]), research design and methodologies (Miller et al., 2017[132]), and the Internet of Toys (IoToys) (Kewalramani et al., 2020[43]; Kewalramani, Palaiologou and Dardanou, 2020[115]; Kewalramani, Kidman and Palaiologou, 2021[44]; Kewalramani et al., 2021[116]; Kewalramani, Palaiologou and Dardanou, 2023[31]).

Although all these studies attempt to examine effective ways technology can support the ECEC workforce to work with children, they do not address directly the ECEC educators' digital competence requirements in different age groups. It is evident that the literature does highlight that ECEC educators need to curate content by incorporating technologies within their play-based and educational practices, primarily for the reason to develop children's DC and digital literacy skills, research needs to examine the DC that might be required for different age groups, their diverse needs and interests, safety, well-being, play and learning. Moreover, as there is limited research on this, research should also focus on the DC of professionals who work with mixed age groups on how they can effectively integrate technology.

Research between 2010 and 2022 examines the use of pedagogical or educational use of technologies in ECEC, such as children's play and learning, engaging in creative processes and teacher's pedagogical knowledge and beliefs limited research is evident, however, on DC and to what extent ECEC educators vary their use of digital tools with children or for other purposes, such as building and sustaining partnerships with parents, collaborating with other ECEC educators and highly important services such as social workers, educational psychologists and medical practitioners and with leadership/governance of the ECEC setting. Examination of the literature showed the following two themes emerged:

Technology used in ECEC is often referred to as educational technology as well, with most research focusing on children over the age of 3. Jack and Higgins (2019[106]) caution us, however, that there is no consistent definition of educational technology and there is much ambiguity evident. Consequently, educators are also confused. In published research, the term technology and its integration in ECEC is often limited to computers or touchscreens (e.g. Chaudron et al. (2015[133]); Edwards et al. (2020[105]); Gillen and Kurcikova (2018[134]); Plowman (2016[135]); Undheim (2020[136]); Yelland (2018[15])). More recent research is emerging with the pedagogical uses of technology in a wider sense to include haptic technology, such as smart toys (Komis et al., 2021[137]), IoToys and artificial intelligence (AI) interfaced toys, and examines the potentialities those offer for imaginative, collaborative activities with children, playful learning and social interactions (Edwards and Bird, 2017[138]; Fleer, 2019[12]; Jack and Higgins, 2019[106]; Kewalramani et al., 2021[116]; Palaiologou, Kewalramani and Dardanou, 2021[45]) or Augmented reality (e.g. Madanipour and Cohrssen (2020[139])) or 3D design and 3D printing (e.g. Hatzigianni et al., (2020[112]; 2021[113])) and educational robotics – (e.g. (Dorouka, Papadakis and Kalogiannakis (2020[140]); Kewalramani et al. (2020[43]); Papadakis and Kalogiannakis (2017[141])).

It is evident from the empirical research that emerges in the last few years that the child as a user of technology is no longer "static", sitting quietly in front of a screen following the instructions of the game or application with which they are engaged (e.g. Edwards et al. (2020[105]); Fleer (2020[121]); Vartiainen, Leinonen and Nissinen (2019[142])). Through play exploration, inquiry activities and creation processes, children and educators now collaboratively use technology in ways that provide a platform for children's language, communication, and collaboration skills (Hatzigianni et al., 2020[112]; Kewalramani, Kidman and Palaiologou, 2021[44]; Undheim and Jernes, 2020[143]). Seminal research in the US conducted by Bers (2017[144]; 2018[124]; 2019[125]), incorporates technologies for enhancing children's coding and computational thinking skills. However, all this research has an element of 'intervention' where the research is 'researcher-led' and less focused on educators' DC development. Research has rather only focused on understanding the capabilities of the technology tool itself, and then inventing pedagogical ways for educators to work with children and technologies in a safe and ethical manner. Literature highlights that part of any PD training for DC is the recognition that technology should be viewed in a broad way and not used as "add-on". This means including various kinds of technology (e.g. haptic, robotics, screens), being used with children's imaginary situation and playful learning. What is important even from earlier research (e.g. Gibbons (2010[145]); Jernes and Engelsen (2012[95]); Mantilla and Edwards (2019[131]); Stephen and Edwards (2018[146]); Stephen and Plowman (2003[118])) is that all pedagogical practices using technology with children should incorporate play elements and be child-initiated where: "teachers have knowledge of and acknowledge the children's varying experiences with digital and at the same time, provide proximal support and guidance when children explore, create, play and learn with technology" (Undheim, 2021, p. 486[147]).

Henceforth, PD training on DC should be oriented by an ideology of child-centred play pedagogy where the child is no longer the "receiver" of information around technology or the passive consumer. The use of technology should be seen as a partnership of children and educators where both guide, scaffold, create, play, explore and learn with and from it. Fotakopoulou et al.'s (2020[8]) study examined the beliefs and experiences of early childhood educators across three countries, England (United Kingdom), Norway and Greece, in relation to the use of touchscreen technology with the youngest children in their settings and indicated that overall educators in the different countries were generally confident when using technology for work/personal purposes but less so when integrating technology with very young children. Nevertheless, educators across all countries were not satisfied with their training and reasons like individual educational philosophy or views towards technology, were important factors affecting most positive views towards using touchscreen technologies in educational settings with very young children.

In relation to studies on pedagogical practices, only a few include children under the age of three (Jack and Higgins (2019[106]) - research with 0–5-year-olds; Fleer (2020[121]) - one to six years old; Jernes and Engelsen (2012[95]) – one to six years old; Lafton (2019[96]) - one to six years old; Ljunggren (2016[97]) - one to three years old; Palaiologou (2016[10]) - two to four years old)). These studies do not examine digital competencies, however, but practices using data collection methods such as interviews and observation of educators and children. All studies reviewed (with children from birth to eight years) highlight the lack of knowledge among educators of how to integrate technology, as well as confusion as to what technology is pedagogically appropriate (e.g. Aldhafeeri, Palaiologou and Folorunsho (2016[101]); Aubrey and Dahl (2014[104]); Hatzigianni and Kalaitzidis (2018[94]); Jack and Higgins (2019[106]); Johnston, Hadley and Waniganayake (2020[91]); McGlynn-Stewart et al., (2017[108]); Palaiologou (2016[19]); Skantz Åberg, Lantz-Andersson and Pramling (2014[148]); Sulaymani, Fleer and Chapman (2018[107]); (Vidal-Hall, Flewitt and Wyse (2020[109])). Nevertheless, another study by Bulca, Ozdurak and Demirhan (2020[149]) presented a distinctive instructional approach supported with visual materials to improve children's locomotor skill learning in Turkish pre-schools and through quantitative analysis, they demonstrated the effects of digital physical exercise videos for improving children's locomotor skill performance.

To conclude, all research reviewed here shows various ways and types of digital technologies used in ECEC with young children. The focus is mostly on children older than three years of age and on play and learning from and with digital tools. Methodological limitations in existing studies are evident (e.g. small, not representative samples; short period interventions; lack of longitudinal impact). A majority of the studies emphasise the need for training in relation to what technologies are suitable for different age groups and what competencies are required so the training can be bespoke. The educators' role is important and central for effective integration (e.g. Belo et al. (2016[126]); Bourbour and Masoumi (2017[150]); Gibbons (2010[145]); Hoel and Jernes (2020[151]); Jernes and Engelsen (2012[95]); Selwyn (2010[152]); Stephen and Edwards (2018[146]); Stephen and Plowman (2003[118])). Nevertheless, all these studies urge for professional learning and training opportunities to support educators, not only in their understanding of technologies and children's experiences with technologies but also creating meaningful opportunities for integrating technologies into everyday practice (e.g. Edwards et al. (2020[105]); Fleer (2019[12]; 2020[121]); Lafton (2019[96])). Finally, there is a need to support educator understanding of children's interactions with technology, not only as playful learning opportunities but also to identify their social and emotional aspects (Hatzigianni and Margetts, 2010[153]; 2012[122]; Miller et al., 2017[132]).

Digital competences for other work processes in early childhood education and care settings

Regarding using technology for other tasks and communicating with parents and other services, again there is very limited research on the DC required. All DC frameworks and research (e.g. Koltay (2011[154]); Erstad, Kjällander and Jarvela (2021[39]); Ilomäki et al. (2016[25]); McGarr and McDonagh (2019[155])) do not separate other tasks from the competencies required for their educational role, such as communicating with parents and other services. Gentikow (2015[156]) proposes that instead of focusing on a set of competencies, the focus should be on developing ECEC workforce skills to retrieve, assess, store, produce, present and exchange information using technologies. In that sense, DC for all required tasks in ECEC should focus on developing educators who are confident to use technology that will work for the learners, parents and the community they are serving. In practical terms, this can be the ability to use technology to retrieve, access, store, produce, communicate and participate in collaborative networks and for professional learning exchange with other colleagues and mentors. Similarly, as was discussed above, when attempting to construct a framework for DC, Janssen et al. (2013[5]) identified 12 different areas composed of knowledge, skills, and attitudes. The framework does not separately outline special DC knowledge and skills that are required by the ECEC workforce to fulfil their daily tasks. It is evident that a DC ECEC educator will understand how to use technologies as a mediatory tool for communication and collaboration as well as knowledge exchange. The ECEC educator will make informed decisions for data management, pedagogical documentation, children's assessments and information dissemination to external stakeholders such as parents, families, mentors, leadership personnel, communities, health professionals and colleagues.

To conclude, as can be seen from all the above studies, although the discourse of what DC is required pedagogically is clear, there is no separation of competencies for other tasks which should be seen as part of the role of ECEC educators.

Based on the literature examined here, we argue that DC for the ECEC workforce should include the holistic development of children, diverse needs and interests, digital divide and equity, collaboration and networking with families and other professionals, leadership and governance of an ECEC setting, programme planning, observations and documentation of children's learning and development.

4. Effective professional development on digital competencies

This section explores examples across countries of effective PD programmes in promoting digital competencies of pre-service and in-service early childhood educators, including the key features enhancing the quality of such programmes.

The review of effective development programmes for the ECEC workforce across countries demonstrated a lack of attention to this level of education and, additionally, minimum work in evaluating and assessing PD efforts. The task of locating PD programmes which had a widespread influence, or a significant impact, became harder due to the variability of early childhood education systems across the world. ECEC may belong (e.g. Australia, Finland, Norway) or not (e.g. Greece) to the Ministry of Education of countries. Ministries or a variety of organisations or institutions, or local councils (e.g. DigiLit Leicester by the Leicester Council for middle school teachers in the UK) might be responsible for offering PD to ECEC professionals. The number of PD efforts is more difficult to locate when it is not centrally organised and administered (e.g. by the Ministry of Education). Our review showed that PD programmes targeting DC or DT for the ECEC workforce are not sufficient.

Possible reasons for this lack of training are provided by the literature and are centred around:

1. Uncertainty about whether very young children should use DT, which are still dividing the sector.
2. Low confidence of the ECEC workforce in integrating DT into their educational practice.
3. Specific demands regarding the type of technologies that are appropriate for young children and how easy to use or available these technologies are (e.g. for children with limited reading or writing skills).

4. Lack of resources and funding for acquiring, maintaining and renewing digital devices (Hatzigianni and Kalaitzidis, 2018[94]; Palaiologou, 2016[10]; 2016[19]).

The review of the relevant literature and exploration of ministries of education in several countries, such as Australia, Canada, China, Estonia, Finland, Greece, Norway, Sweden, the United States and others, revealed a range of PD programmes focusing on DT which were specifically designed for the ECEC workforce or for educators of all levels of education which also included them. Programmes offered to pre-service and in-service ECEC educators are usually separate, but when combined the results are very encouraging (Arikan, Fernie and Kantor, 2020[157]; Polly et al., 2010[158]). In this report, programmes which had a successful impact on the sector are presented, and which were implemented on a larger scale (excluding small case studies and programmes which trained less than 20 educators).

Our findings revealed that the PD landscape is extremely diverse and depends on the country's government organisation (e.g. the division of government responsibility for ECEC in different jurisdictions such as in Canadian provinces and territories, in Australian states and territories, in states in the United States) and on whether the ECEC sector is under the supervision and has clear guidance and policy from the respective Ministry of Education. PD programmes at a national scale are rare nowadays and most programmes are designed and delivered by universities, colleges, local councils, private PD institutions and digital technology companies. The conceptualisation of these programmes is a vital dimension to consider when examining their influence and effectiveness. A clear conceptual framework which underpins the design and delivery of the programmes is a prerequisite for their success and long-lasting impact. Seeing ECEC educators as professionals, needing and having a right to continuous development and not a one-off training session, is critical for becoming confident with DT. ECEC educators have a deep and holistic view of children's development and, therefore, are in a good place to realise and acknowledge the value of their own development as pedagogues and educators. Unfortunately, our exploration of the literature has found that there is still a lack of substantive PD programmes which value educators' input and active participation. Examples of national PD programmes in DT from Greece and China are centrally designed and have not considered ECEC educators as evolving teachers, as will be discussed in the following sections. Additionally, the delivery of most programmes has also changed with educators seeking flexible, personalised, online or blended modes which is also a sign of a more advanced familiarisation with online tools such as Learning Management Systems (LMS), online platforms and social media. Emerging research in this field is uncovering the key role of social media, such as Twitter, in providing PD opportunities to educators and for a growing interest and preference in this type of communal and networking prospects (Carpenter et al., 2020[159]; Carpenter and Krutka, 2015[160]; Pölzl-Stefanec, 2021[161]). In Australia, Straker et al.'s (2022[162]) 2022 and ongoing research as part of the Centre of Excellence for the Digital Child focuses predominantly on children's DC and digital literacy development. Furthermore, only more recent research has looked at investigating the implementation and evaluation of ECEC educators' integration of technologies as an evidence-based PD programme (Kewalramani, Palaiologou and Dardanou, 2023[31]; Victorian Department of Education and Training, 2021[163]).

The following section will present examples of PD programmes around DT specifically for the ECEC workforce. First, an analysis of workforce development for pre-service ECEC educators is discussed, followed by in-service educators' DC professional development. The terminology used follows the same terminology the programme/example was using, e.g. some older programmes referred to terms such as digital skills, ICT, or technology or technological proficiency, whereas more recent programmes used terms such as: digital literacy and digital competence. Each section will start with some overview of the gaps and needs, will then elaborate on specific examples and their critique and at the end will briefly synthesise specific suggestions, recommendations and implications for the sector.

Pre-service training

Studies with pre-service educators or in initial teacher education (early childhood and primary education) focus mostly on teachers' beliefs and attitudes around the use of DT and teachers' low confidence around digital tools (Ottenbreit-Leftwich et al., 2010[164]; Palaiologou, 2016[10]; Tveiterås and Madsen, 2022[165]). Most higher education systems around the world now include compulsory subjects around digital technology in diverse forms and to a different extent. Courses or subjects might concentrate on learning to use specific digital tools (such as: presentation software, educational robotics, music and draw software, and mixed reality teaching environments) and in some cases, extra selective subjects are offered to further enrich DC (Bautista and Boone, 2015[166]; Luo, Berson and Berson, 2021[33]; Masoumi, 2021[37]). Covering a broad range of technology-focused subjects would seem adequate for most pre-service educators, at least for the countries which offer university degrees for their ECEC workforce. As evidenced by a large, representative survey of 1 439 institutions with teacher education programmes in the US (Kleiner, Thomas and Lewis, 2007[167]), 85% of those programmes offered at least one educational technology course (ranging from one to four credits). However, the higher education (HE) sector still struggles to design an optimal pathway for its educators to empower them in feeling confident and sufficiently equipped to integrate technology into their teaching and learning (Tondeur et al., 2017[168]). A good example is reported by Romero-Tena et al. (2020[83]) in Spain. Although the focus on digital skills is strong and European organisations have created a range of frameworks to help educators and governments deal with the increased digital literacy skills demand, there is no specific framework or guidelines of what these skills are and to what extent should they be achieved. The researchers postulate that the presence of technologies in ECEC teacher education programmes is still scarce. In most cases, those pre-service teachers who venture to incorporate DT in their practice use their own resources.

A similar picture is drawn in Turkey (Çebi and Reisoğlu, 2019[169]) where the DC of ECEC educators is described as "moderate". A Swedish study (Masoumi, 2021, p. 3010[37]) adds to these results the low confidence pre-service educators have in implementing digital skills in their future educational practice. The study revealed a gap between skills and knowledge on behalf of the educators and their ability to incorporate technology into their practice. Consistently in China (Luo, Berson and Berson, 2021[33]) the emphasis is still on technical skills which are even outdated in some cases and not on integration in pedagogical practices. In Norway, the fact that professional DC is named as a focus area in pre-service early childhood education regulations (Norwegian Ministry of Education and Research, 2012[170]) is a factor that some early childhood education institutions include in their subject descriptions knowledge and competencies related to the use of digital technology or digital judgement (Dardanou and Kofoed, 2019[27]).

Considering the above limitations in university offerings, several attempts to address these extra needs have been made. In Spain, in the Andalusian community, great variability among eight universities led to an intervention study, in the 4th year of the Degree in Early Childhood Education at the University of Seville during three academic years (2016/17, 2017/18, and 2018/19) with a total of 535 students, mostly women, with high personal use of digital tools (Romero-Tena et al., 2020[83]). The subject was: "Information and Communication Technologies Applied to Early Childhood Education" and was based on three strong pedagogical and technological frameworks (ISTE (2017[85]); the National Association for the Education of Young Children (NAEYC/Fred Rogers Center, n.d.[171]); the European DigCompEdu (Redecker, 2017[172])). The subject was taught in all three years by the same professor. They used a pre- and post-questionnaire (The "Questionnaire for the Study of the Digital Competence of the Student of Higher Education" or CDAES, Gutiérrez-Castillo, Cabero-Almenara and Estrada-Vidal (2017[173])). They found a moderate increase in students' self-perception in "different informational competencies linked to the integration of ICT in the curriculum of children, such as creativity and innovation" (p. 13[173]) and their profile changed from a low profile ("newcomer", "explorer") to a medium-high profile/level ("integrator", "expert") according to the European framework of DC. The critical role of training in initial teacher education was underlined throughout the study as one of the main causes of inadequate use of digital tools in ECEC.

Further looking at the European context, in Sweden, despite a large investment in ICT and comprehensive policies to support innovative uses of DT, the technological integration in ECEC is still challenging for teacher education programmes (TEPs) (Masoumi, 2021[37]). ECEC educators in Sweden complete a bachelor's degree with an emphasis on creating a rich learning environment with the help of DT as described in the Swedish curriculum for pre-schools. However, pre-service educators as in many other countries (e.g. Norway, see Instefjord and Munthe (2017[174]) or Krumsvik (2011[175]); US, see Brown, Englehardt and Mathers (2016[176]); Hong Kong, see Hu and Yelland (2017[177])) appear less confident and are feeling that they are not well prepared to integrate digital tools in their educational practice (Masoumi, 2021[37]). Similarly, as mentioned above, in a cross-sectional study in Turkey with 518 pre-service educators (56 pre-school educators, Çebi and Reisoğlu (2019[169])) which examined DC through the completion of an online questionnaire, revealed that they were not confident in creating digital content, safety and problem solving. However, no specific elements of training and how they were influencing results were examined in these two studies.

In Australia, extensive investment in educators' PD has been carried out in the last 15 years (Murcia, Campbell and Aranda, 2018[178]). The "Teaching Teachers for the Future (TTF)" national project aimed at improving the technological proficiency of pre-service and in-service educators of primary, secondary and higher education. Early childhood educators were not included in this training – only the ones who could teach in the preparatory year of primary education in Australia (children aged 5 to 6). All 39 Australian teacher education institutions were involved in the project together with the provision of online resources to further enhance teachers' digital training. The design of the project was pedagogically sound and research-informed. The project adopted the TPACK theory which emphasises the interrelations of pedagogical and technological knowledge with discipline (content) knowledge. Educators were trained to use digital tools (technology) in an integrated way (pedagogy) to support their content knowledge, in other words, educators learnt how to transform their teaching and learning methods with the help of technology. Resources from this project were widely used and included: video footage of classroom practices, annotated lesson plans detailing the use of ICT, advice on the use of technological tools, research articles, educators' voices, tools to support collaboration and planning and others (see all the details in Romeo, Lloyd and Downes (2012[179])). Recommendations arising from this effort underlined the importance of contextual factors, the identity and shared understandings of educators, the existence (or not) of communities of practice in promoting DCs, the vital role of leadership and the challenge of sustaining funding for national projects (Murcia, Campbell and Aranda, 2018[178]; Romeo, Lloyd and Downes, 2012[179]).

A different approach to educators' training with digital technology is proposed by several researchers who suggest the integration of DT throughout the teacher education curriculum and the necessity to include as many as possible authentic experiences (e.g. Niess (2005[180]); Ottenbreit-Leftwich et al. (2010[181]); Polly et al. (2010[158])). One such approach was adopted in a North American state university (Midwestern US, Brown, Englehardt and Mathers (2016[182])). Students completed a three-semester PD to acquire a teacher certification to teach in early childhood through grade six classes. The PD did not offer a specific, standalone technology course, but encouraged the integration of digital tools in all their coursework. A small number of students (N = 20) were each loaned an iPad to use for the duration of the study semester. Students were using the iPad in multiple forms and got familiarised with the play, assessment and documentation affordances of the digital tool. This proved to be very beneficial for students and not only enhanced their critical thinking and digital skills, but also provided opportunities to transform their teaching philosophy. Researchers concluded that providing student teachers with digital tools during their professional practicums and having a clear, detailed conceptual framework (they adopted the UTAUT framework from Venkatesh et al. (2003[183]), which includes four core constructs which influence the acceptance and use of technology: performance expectancy, effort expectancy, social influence, and facilitating conditions) contributes to developing positive attitudes and beliefs around the use of digital technology, enhances digital citizenship and democratic practices in future education. Similarly, studies have supported the incorporation of DT in early field experiences to enhance authentic technological experiences (Lux, Bangert and Whittier, 2012[184]).

A critical suggestion from the Chinese studies refers to the need to establish a continuum of professional development, setting the foundations in pre-service educators, but to extend this to co-operating teachers, in-service teachers and university professors. The Chinese government has made progress in formally recognising the importance of pedagogical integration of DT in early childhood, but the approach to training remains "teacher-centric" (Luo, Berson and Berson, 2021, p. 1172[33]). Additionally, the Spanish study (Romero-Tena et al., 2020[83]) argues about the need for training to target self-perceptions and aims at a higher digital competence profile, helping pre-service educators see themselves as experts.

An exemplary PD programme under the Head Start early childhood education umbrella, took place in Ohio and had the name: "The Teachers Learning and Technology Project" (TLT, USD 2 million, 1999-2002). This technology project was funded under a large-scale, federal project for enhancing the technology proficiency of all teachers ("Preparing Tomorrow's Teachers to Use Technology", the PT^3 project, which started in 1999 and had over USD 275 million funding over 440 consortia. The TLT Project website stated the purpose of the project as "to improve the quality of early childhood teacher education programmes by enhancing Head Start teachers' academic opportunities through increased exposure to and use of technology in authentic and culturally relevant contexts" (Arikan, Fernie and Kantor, 2020, p. 1837[157]). These educators were adult learners and were studying at the same time with working in early childhood settings. The programme adopted a strong social constructivist theoretical framework, seeing technology as a social learning activity and emphasised the importance of forming communities of learners to enhance their technological proficiency, networking and collaboration. They built on-site computer labs for both educators and parents to be able to interact and collaborate. Educators had assistance in their double roles by having permission for "early release to attend college classes, flexible computer lab hours, payment for books and tuition, helping teachers in scholarship applications, inviting faculty partners to their meetings" and similar" (p. 1842[157]). Educators needed technology to help them achieve their goal, to finish their early childhood degree, and in the process of doing that they experienced a transformation in their confidence and attitudes toward technology. Their fears disappeared and the accessibility to authentic, social learning with people they could trust, such as their peers, technology instructors, co-workers and children, contributed to the enhancement of their emotional, behavioural and cognitive skills. The social support they were receiving was equally important as the technical and learning support, resulting in making them feel confident and secure with their technological endeavours. An "ecology of learning that scaffolds technology learning and provide contexts of interactions and communication through ongoing community support and collegiality" (p. 1844[157]) was created which sustained interest and engagement of adult learners. These organic characteristics of PD were considered extremely positive by the participants and offered new insights into how an effective programme could be designed, delivered and sustained beyond its completion.

To summarise, HE has invested in DT courses in ECEC by adopting standalone (e.g. technology-focused subjects) or integrated PD (e.g. encouraging the use of digital tools in all subjects). Our review showed that pre-service educators' attitudes and perceptions are more positive than their satisfaction with integrating technology in their pedagogical practice (Alelaimat, Ihmeideh and Alkhawaldeh, 2020[185]; Casillas Martín, Cabezas González and García Peñalvo, 2019[60]; Drent and Meelissen, 2008[186]; Galindo-Domínguez and Bezanilla, 2021[36]; Kay, 2006[187]). However, the expectation to transfer knowledge and skills to their future classrooms by attending two or three educational technology courses seems to be hard to achieve (Brush et al., 2003[188]). In contrast, when a more holistic, research-based and theoretically strong approach is followed, results are more encouraging (e.g. Australia and the US example). Pre-service educators worry more about how to take advantage and pedagogically implement all the new digital tools with their children in their everyday practice and they need more support in this area.

In-service training

Through the careful examination of the literature and several PD programmes for the ECEC workforce which have been based on research and evaluated, two main categories of PD have emerged. The first category includes small-scale PD (Gaible and Burns, 2005[189]) site-based, school-centred and locally/community focused. ECEC educators who appreciate face-to-face training will benefit from such tailor-made programmes. The self-directed approach is also gaining ground among educators due to its flexible, dynamic and adaptable nature. Considering also that the ECEC workforce engagement with digital learning tools during the pandemic was evident, it makes even more sense to reflect on the ways of training and urgent advancement of educators' DC in handling e-learning platforms, teleconference applications. The exploitation of those possibilities should be further explored in a more systematic and methodical way.

The second category of PD includes large-scale and national efforts which should be carefully designed and strategically planned to ensure their efficiency, effectiveness and continuity.

Large-scale, national level training initiatives

National, large-scale professional development programmes usually target all levels of education. Such programmes may have the advantage of being freely available and centrally designed, but they adhere more to the "standardised model" which is utilised to disseminate a large volume of knowledge, content and skills often via a "cascade" or 'train the trainer' approach (Gaible and Burns, 2005[189]). One such programme has been implemented for more than 20 years now in Greece by the Ministry of Education. Co-funded by the European Union, the programme started in the 1990s and since then has been through many iterations. Initially, all educators were invited to be trained in basic ICT skills, such as learning to use office software, sending emails etc (A1 level of training, around 50 hours). Educators of all levels were invited to attend the training outside their working hours. To complete this initial training, educators had to sit exams and get a certification. After getting their certification, educators had the option to complete B1 (36 hours) and B2 (42 hours) levels of more advanced digital skills and learning about ICT pedagogical integration in their level of education. To complete this second level of training, educators had to attend an intensive programme each week, outside their working hours. The programme is still running. To complete the programme, they must design their own educational scenario and implement it in their class, together with exams. The completion of the second cycle of training provides educators with a certification and with extra points of recognition when applying for an administrative or management position in public education. Initially, early childhood educators and primary teachers were trained together, but later the unique nature of the early childhood workforce was realised and they were trained separately.

The programme followed the "train the trainer" approach, with universities being the leaders in most cases. It is estimated that more than 30 000 educators will benefit from the B1 level of the PD programmes and more than 5 000 from the B2 (see more information on the website https://e-pimorfosi.cti.gr/moodle-b2/). Though there is no official evaluation of the programme by the Ministry of Education, several studies have examined small, not representative cohorts of educators (including early childhood and primary teachers) to identify the impact of this programme on their teaching and learning. Findings of these studies concluded that the volume of knowledge and intensity of the programme was its main disadvantage and that its success was purely based on educators' willingness and hard work despite serious barriers such was the lack of technological equipment, lack of time and a heavy academic load for educators and trainers (Lympou, 2018[190]; Symenonidis, Goumas and Savvidou, 2014[191]; Triantafyllou, 2018[192]; Zetta, Papakonstantinou and Apostolidis, 2009[193]). Educators appreciated the opportunities to collaborate and create communities of learning and the ones who completed the whole training were more positive towards the use of technology in their class (Lympou, 2018[190]). However, a study by Xafakos et al. (2016[194])on primary and kindergarten educators found that the programme's requirement to design their own, very detailed educational scenarios with DT demanded much work and many hours (outside working hours) and were rarely used after the completion of the training.

Similarly, in China, there have been several training levels for in-service educators offered nationally (see for example "School to School network project", "Teachers' Professional Development for ICT in Education", "Modern Distance Education for Schools in Rural Areas Projects", "National Educational Technology Standards for Teachers", Liu, Toki and Pange (2014[195])). Pre-school education in China does not belong to primary education and pre-school educators are not included in the above-mentioned projects. China has made substantial progress in digitalising ECEC teaching and teacher education in the past decade, especially in improving digital infrastructure (Luo et al., 2021, p. 6[34]). Mobile use and social media use by the ECEC workforce also increased considerably from 2016 – 2019. Nevertheless, national training programmes for all ECEC educators (in urban and rural areas) did not satisfy their needs. Studies found that despite the improvement of infrastructure, educators were reporting the lack of quality training as one of the most important barriers to effectively integrating technology in their teaching (Dong, 2018[196]). Many of them used online searchers to learn how to integrate digital technologies into their practice. The strongest criticism was that educators' training centred around basic technical skills and "neglected pedagogies" (Luo et al., 2021, p. 12[34]).

Norway, on the other hand, as also discussed in other parts of this report, has made a step further and created a curriculum for the ECEC workforce which incorporates DC and digital judgement as core themes. The existence of a Norwegian framework for ECEC educators is an enabler for training as it provides a fertile ground for trainers to work on and ultimately contributes to the integration of DT in their didactical and pedagogical practices. Norway was also a pioneer in considering the ECEC workforce in regional areas, another important dimension of PD programmes. An evaluation of the regional scheme for ECEC-based competence development, which includes digital praxis as one of the focus areas, showed generally positive attitudes to the scheme and wishes for closer professional collaboration between ECEC and the higher education sector (Reinertsen et al., 2020[197]). ECEC educators assess themselves and reflect on their own and collective actions. The Regional Scheme for ECEC Professionals proved to be very successful and effective. Finally, the Norwegian Directorate for Education and Training has developed an online DC package that is free and available to all, further supporting and encouraging the integration of DT in educational practice.

In Malta, the National Strategy Digital Malta 2014-2020 is related to all educational levels and focuses on the challenge of capacity building, i.e. improving educators´ digital competencies and as a result, enriching their teaching methods. It emphasises, that students should fully benefit from digital literacy, and promotes citizens' access to and use of ICT. The strategy prioritises the improvement of ICT competencies, media literacy, female participation in science, technology, engineering and mathematics (STEM) education and safer use of the Internet (EC, 2019[198]).

In Estonia, the state policy for the development of an educator's DC is based on several legislative and regulatory acts. The educational system is focusing on the formation and integrated development of an educator's professional competence (Mukan and Noskova, 2019[199]). The gradual, open and consistent actions of the government and the Ministry of Education and Science in this area, as well as the results of changes implementation, are not sufficiently investigated but are essential to Estonia since their educational system was being reformed. A thorough examination of the results of new digital policies directly in Estonian schools is strongly recommended. Sillat and Kollom (2017[200]) added to these recommendations the need for the development of DC for academic staff after completing a training programme with pre-service and in-service Estonian educators.

In Ireland, the Digital Strategy for Schools presented a clear vision, but it is limited only to schools and does not include ECEC (Irish Department of Education, 2022[201]). However, a new strategy for ECEC which includes PD in general as part of the new workforce development plan is to be introduced (Government of Ireland, 2021[202]). Within this is recommended that the new strategy needs to recognise that learning starts from birth and proposes that part of the skills and knowledge of the Early Years Educators should be the: "Ability to implement pedagogical strategies to support children's emergent language, literacy, (including digital literacy), numeracy, creativity, early science, technology engineering, arts and mathematics (STEAM)" (p. 130[202]).

In Italy, Balduzzi and Lazzari (2015[203]) analysed a different aspect of PD, mentoring practices, in a national programme for the workplace-based professional preparation of pre-school and primary school educators and concluded that this method can increase their professionalisation and their digital skills. In line with the Italian study, the MENTEP (MENtoring Technology-Enhanced Pedagogy) project was a European Policy Experimentation that addressed the need in EU policies for all educators to be able to innovate using ICT and for improved data on their digital competence (Taddeo et al., 2016[204]). MENTEP aimed at building competence in the pedagogical application of digital technology using a self-assessment tool linked to competence development opportunities. To achieve this, a sound understanding and detailed evaluation of educators' professional development in DC is recommended, together with the testing of promising innovations such as "blended models of assessment based on online tasks and authentic experiences" (Taddeo et al., 2016, p. 59[204]).

Finally, in New Zealand, the Ministry of Education had an ICT strategy and 21st Century practice in teaching and learning plan that focused on integrating digital education. New Zealand offers us a new perspective on PD with supporting linkages between communities and industry to ensure collaborations in the design and delivery of education and training (New Zealand Ministry of Education, 2019[205]). New Zealand already has initiatives such as ICT Graduate Schools and Māori and Pasifika Trades and Training to prepare for the modern workforce including internships, and employers working directly with education providers.

Overall, large-scale programmes that have been evaluated as successful have met the needs of teachers, derived from bottom-up approaches and are based on ECEC settings' contextual characteristics. Transformative practices have been based on hands-on digital workshops and learning networks. Sustainability of digital professional development is promoted by creating communities of practice, learning networks, social support and mentoring schemes. Time is essential for an educator's professional development as well as financial support in covering teaching costs and updating equipment. Peer collaboration, self-assessment, reflection, direct classroom application and trialling, plus some external input from universities or technology experts are also recommended (Carpenter et al., 2020[159]; Hennessy and London, 2013[206]). A curriculum or a pedagogical framework which also elaborates on DC facilitates digital integration especially when teachers feel more confident, connect with others and have opportunities to test out equipment and software on multiple occasions and in a range of spaces (Kozma, 2003[207]).

Small-scale, local-level training initiatives

Steering away from national programmes, in other countries, such as the US, successful efforts seem to have focused mostly on a clear conceptual framework, appropriate pedagogies and holistic approaches. These effective models are closer to what Gaible and Burns (2005[189]) describe as a "site-based" professional development model. This model is designed based on local needs and reflects local conditions. The duration of the programme is usually long and the intensity is medium. Aims and objectives of the programme are clearly defined and promote profound and long-term changes in teaching practice. Almost always the programmes are underpinned by research (action research or design-based research) and the involvement of academics and researchers is welcomed. One such exemplar programme was implemented by Head Start in Early Childhood Education in the US. The Department of the Chicago Public Schools and Erikson Institute, in collaboration with a Graduate School in Child Development, implemented the "whole teacher professional development programme in technology" specifically for the ECEC workforce to transform their teaching practices with innovative tools and strategies (Chen and Chang, 2006[208]). Educators (N = 175) had two computers in their classrooms for which 134 had completed a two-day session of introductory computer training. The remaining 41 educators completed a yearlong professional development programme in technology based on the *whole teacher* approach. The four main characteristics of the approach were: multidimensional, domain-specific, integrated, and developmental (see more details in Chen and Chang (2006, p. 2[208])). Educators were offered 26 sessions, 52 hours over a school year. Each session was around two hours with the instructor and there was a week between sessions for educators to practice and test what they have learnt. Educators evaluated the programme very positively and reported "using more different teaching methods in computer work with children and producing a greater variety of computer-generated instructional materials than nonparticipants did" (Chen and Chang, 2006, p. 11[208]). Participants also appreciated the hands-on experiences, the bridging of the gap between theory and practice and the familiarisation with children's software. Overall, the programme emphasised the benefits of moving towards a "teacher development" approach instead of the "training the teacher" approach (pp. 11-12[208]). A developmental approach will provide educators with ample opportunities to practice and will increase their self-efficacy over time, leading to greater technological proficiency, knowledge internalisation, increased motivation, positive attitudes and a positive mindset (Borko, 2004[209]; Chen and Chang, 2006[208]).

Another successful programme with kindergarten to Grade Four educators was implemented in Canada (Jacobsen, Friesen and Brown, 2018[210]). The Early Learning and Technology Research Community of Practice (ELT-RCOP), which included four school jurisdictions in the province of Alberta (Canada), a research team from the Werklund School of Education, University of Calgary, mentor teachers from the Galileo Educational Network, a professional learning and leadership organisation in the Werklund School of Education, and the provincial ministry for education, Alberta Education (Jacobsen, Friesen and Brown, 2018, p. 420[210]). The programme had similar traits to the Head Start programme in the US. It was research-based, had a long duration of two years and was socially strong within a research community of practice. Mentor educators visited the school (three full days in the first year) to guide educators in designing academically rigorous work, assessments for learning, using technology appropriately for communication and networking and other useful tasks. Though it commenced with face-to-face sessions, in the second-year educators preferred a more flexible approach to training through on-demand support. Mentors offered additional online/offsite support through video/audio conference and email, but also on-site professional learning sessions when requested. The content of professional learning included the use of mobile phones and iPads for supporting language development and early literacy, 21st century skills, digital media and differentiated instruction, Web 2.0 tools and digital cameras (p. 420[210]). Both educators and students formed their own communities of practice which increased and maintained their technological engagements, offered them the chance to design, create and share their own content and promoted collaboration beyond their school. As the authors explain, "It was evident the social construction of knowledge was promoted through technology" (p. 433[210]) an indication also adopted by the older programmes of Head Start and the PT^3 model.

In line with many of the previously mentioned programmes, but with a focus on a "train the trainer" model, the "Technology Users Group" (again in the US) was defined as: "a group of ECEC professionals who:

1. Have a shared interest in information technology (IT) and assistive technology (AT).
2. Are committed to developing new skill sets about an array of IT and AT devices and integrating them into planned classroom activities.
3. Are supported for participating in the technology user group.
4. Share their learning with other ECEC professionals" (Parette et al., 2013, p. 172[211]; 2007[212]).

The sessions were ongoing and on multiple dates, and technology toolkits were provided to the ECEC workforce for utilisation as instructional products, which were two of the strongest characteristics of the programme. The success of the programme has been documented in several research projects (e.g. National Center for Technology Innovation and Center for Implementing Technology in Education, (NCTI/CITEd, 2006[213]); Parette et al. (2008[214])). Very little is known about the long-term impact of this programme after the professional development of ECEC educators was completed, however, and whether those groups were sustained and expanded or not (Parette et al., 2013[211]).

Finally, a very recent professional development programme in Austria (Pölzl-Stefanec, 2021[161]) argues for the untapped potential of online approaches to the professional development of the ECEC workforce. They also referred to the difference between European and American examples of professional development, supporting the American ones which have exploited e-learning and distance education for promoting DC for ECEC educators for many years and with successful results. They also offered useful suggestions of how these online courses could be effective: "must be self-explanatory", include "introductory courses, tutorials, or short user's guides" and have a "user-friendly interface" for the ECEC workforce (Pölzl-Stefanec, 2021, p. 2205[161]).

Overall, this review located a range of small-scale programmes and although the number of these programmes around the world cannot be easily estimated, successful features seem to be consistent. More findings around these features and what is next for the professional learning of the ECEC workforce to pave the way for them to become digitally competent professionals are presented in the next sections.

Key features of successful professional development on digital competencies

The search of the literature and the study of many PD programmes contributed to the synthesis of a list of successful PD features for DC. Based on the evidence discussed in this literature review we propose three basic dimensions of PD which focuses on advancing ECEC educators' DC:

- **Structural features**: features that need to be considered before the start of the PD and are dependent on budget, duration, number of ECEC educators, their needs, their technological background and experiences, their contextual circumstances and community characteristics. Sustainability issues should also be carefully considered in the initial design of the PD.
- **Content features**: the actual 'lessons' ECEC educators will complete and/or expand on. The technical and pedagogical knowledge they will explore and practice.
- **Quality Features**: the way/s the PD will be evaluated and the improvements which will be suggested after each PD effort. ECEC workforce voices and reflections would be invaluable in this stage. The evaluations should be carried out at different stages (e.g. not only at the end) to prove the impact and the duration of this impact.

Figure 1 illustrates this as well as the list of features under each dimension required for the success of future PD programmes in DT. All three dimensions are interconnected and one influences the other. The first dimension includes the design and the delivery of PD, for which it is crucial to consider all staff and identify their needs, special situations, idiosyncrasies, and possible insecurities. The delivery could capitalise on a range of possibilities (e.g. via social media, hybrid models, LMS etc) to be flexible, but not distant. The second dimension focuses on content and underlines the theoretical and research basis of the programmes. ECEC educators do not have a strong technological background and they do not teach specific subjects. Their approach to learning is holistic, interdisciplinary, based mostly on play, projects and inquiries. They focus more on positive dispositions that need to be developed and supported in early childhood and not on teaching content of subjects. Therefore, the content dimension should be different to the one for older levels of education. Practical, useful, relevant experiences with technology and how digital tools can be integrated in their daily educational, pedagogical and administrative practice are of primary importance. The ways DT enhance collaboration with parents, other professionals and other colleagues are also vital. Moreover, clear, strong theoretical foundations contribute to successful execution, evaluation and reflection on the quality of the programme (the third dimension). Critical reflection and assessment facilitate continuous improvements.

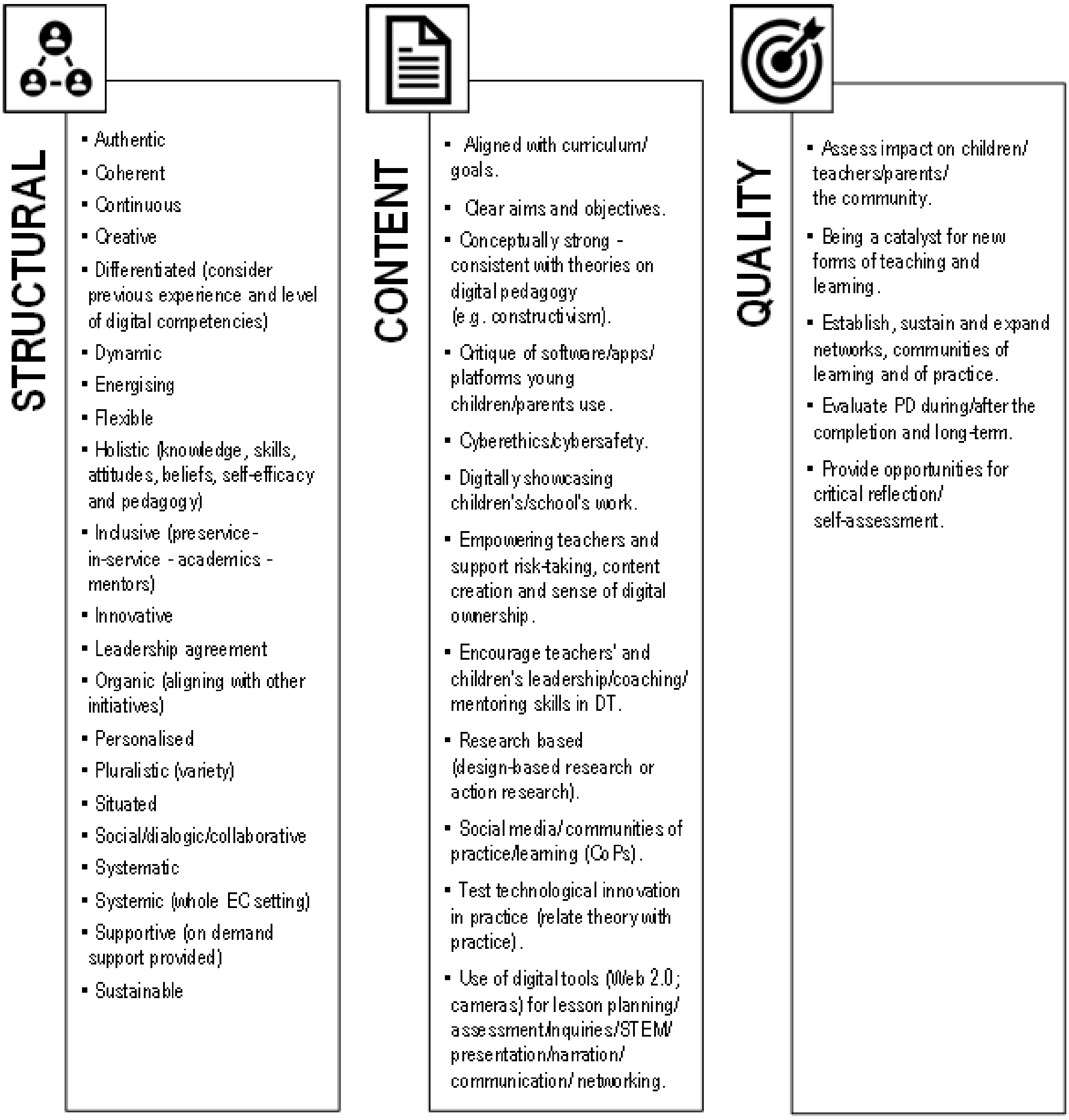
Using digital technologies to enhance the quality of training

The exponential growth of DT has transformed the affordances and modes of PD for all educators. Research in this area has also expanded significantly highlighting the fertile ground for further improving PD with the use of innovative digital tools. Focusing specifically on education, a number of tools have been developed to support online communities such as social media, WeChat (Xue et al., 2021[215]); Twitter (Carpenter et al., 2022[216]; Trust and Pektas, 2018[217]), virtual meeting spaces where virtual teams collaborate and plan together (Charteris, Berman and Page, 2021[218]), video conferencing technologies, video editing tools (Cherrington and Loveridge, 2014[219]; Danniels, Pyle and DeLuca, 2020[220]; Pickering and Walsh, 2011[221]) and free web-mediated resources (Bates et al., 2019[222]) and to promote educators' observational, reflective and assessment skills proving that DTs are useful in a range of activities in educational practice.

New ideas for designing PD with the help of DT have also expanded, especially after the trauma COVID-19 caused to all educational systems. Having a digital or virtual coach/mentor for a long period of time to assist with the integration of technology across the curriculum (Grierson, Gallagher and St Hilaire, 2022[223]; Zimmer and Matthews, 2022[224]) is suggested as a reliable and cost-effective solution in recent literature. Faculty/School in-residence programmes to establish digital training collaboration between universities and schools have also been recommended (Herro, Hirsch and Quigley, 2022[225]). Following flipped classrooms as a new pedagogy, flipped PD with the use of DT has also been tested as a design model with positive effects (Yurtseven Avci, O'Dwyer and Lawson, 2020[226]). Organising technology-enhanced conferences (Spilker, Prinsen and Kalz, 2020[227]) has increased the focus on the potential of social media and online learning communities. Finally, (Muñoz-Carril, González-Sanmamed and Fuentes-Abeledo (2020[228]) investigated the role of blogs in pre-service educators' learning opportunities. Their findings suggested a positive impact on educators' active participation, reflective thinking, self-evaluation and co-evaluation of practice.

Design learning models (e.g. ADDIE by Trust and Pektas (2018[217])) and numerous models of evaluating PD with the use of DT (Ahadi et al., 2021[229]; Peterson and Scharber, 2018[230]; Smolin and Lawless, 2011[231]) have been developed to further enhance efficiency and usefulness of PD for educators. Design-based research (or Educational Design Research) is often recommended as a good-fit for studies which examine PD models with DT. Future research avenues are emerging considering PD in cyberethics, cybersecurity and cybersafety, topics that have not yet been sufficiently covered in teachers' PD (Pusey and Sadera, 2012[232]).

Figure 1. Dimensions of effective professional development on digital competencies



Source: Authors' elaboration.

Overall, studies argue for a systemic approach to DT. Flexibility is gaining ground together with personalised, tailor-made approaches. Issues of sustainability and covering costs are not yet solved but the social nature of educators' profession is crucial in PD efforts too. Programmes which aim at transforming teaching and learning with the help of technology seem to resonate with the ECEC workforce and have a long-lasting impact compared to the unidimensional ones which only target digital skills.

5. Summary

The key findings of the thematic analysis can be summarised as follows:

- There are limited DC frameworks and policies in ECEC.
- There are few theoretical models for educators' development of DC. The dominant ones are the technological pedagogical and content knowledge (TPACK) and the Substitution, Augmentation, Modification, Redefinition (SAMR) model. TPACK aims "to explain how understanding of educational technologies and pedagogical content knowledge (PCK) interact with one another to produce effective teaching with technology" (Koehler, Mishra and Cain, 2013, p. 14[59]). SAMR is a descriptive framework that maps different educational uses of technology hierarchically against levels – progressing from Substitution ('doing digitally' what has traditionally been carried out using conventional resources) through to Redefinition (curriculum, pedagogy and practice reconceptualised through DT). Although these two frameworks are general to education, they can be relevant to training needs for the ECEC workforce.
- Digital frameworks for ECEC workforce development should be child-centred. Educators should be seen scaffolding children's learning and showing willingness to learn with and from technologies in partnerships with parents, communities and policy makers. It is equally important, however, for the workforce to have core knowledge to protect children from risks inherent to DT.
- The strengths and limitations of the DC frameworks for ECEC workforce development demonstrated a need to recognise the importance of technical and procedural skills, ethical and safe choice of technological resources and the social/collaborative elements of the frameworks. Critical reflective practice is needed to create pedagogical capabilities and dispositions, as part of both teacher education programmes and in-service training.
- The use of DT for pedagogical purposes demonstrated a disconnect between home and ECEC settings. The conclusion is for DT to be "work together" to improve the workforce DC and to build and sustain partnerships with parents.
- There is limited research and practice for children under the age of three and more is needed.
- The additional workforce skills and tasks should recognise the evolving convergence of information, digital and media literacies.
- Much caution is still evident in the workforce about the integration of DT in ECEC, based on doubts of whether and how very young children should use them. These debates are still dividing the sector and limiting skills development.
- Time is essential for workforce development, as is financial support in covering training costs and updating of equipment. Peer collaboration, self-assessment, reflection, direct classroom application and trialling, plus external input from universities or technology experts are also recommended.
- A pedagogical framework which elaborates on DC can support workforce development by providing shared understanding about the potential roles of DT, enhancing educator confidence, enabling connection with others and providing opportunities to test out digital practices.

Conclusions and recommendations

The findings of this review revealed a need for a systemic approach to PD on DC for ECEC professionals. DT are embedded in many aspects of children's lives and ECEC should be responsive to this reality by considering a variety of approaches regarding the extent and type of uses of DT in ECEC settings. The ECEC workforce uses DT for a wide variety of tasks. Personalised use has improved (Hatzigianni and Kalaitzidis, 2018[94]; Palaiologou, 2016[10]) but the ECEC workforce needs more knowledge and skills in realising how DT can be integrated into their educational and pedagogical practice. For more than 20 years now studies have been arguing for the need to offer effective and sustainable PD to the ECEC workforce, who seem to be a group "left behind". Despite the undeniable value of their work, the ECEC workforce seems to be the "last horse in the race" of the technology revolution and responsibilities for addressing their relative lack of preparedness are shared by many actors. More emphasis on the development of DC in ECEC is required together with more research and policy support.

Research for many years has underlined the impact of personality traits, attitudes, beliefs, pedagogical philosophy on ECEC educators' adoption of DT. This dimension will continue to play a primary role in the future as demands increase, coupled with rapid technological changes, meaning that pressure will stay high on the ECEC workforce to have the skills to integrate digital technologies in their pedagogical practice in a safe way. PD programmes about DC need to account for these challenges and offer the security, empowerment, confidence and support the ECEC workforce requires to be able to overcome any barriers or self-doubts. PD programmes should provide opportunities for ECEC educators to explore the pedagogical value of digital tools and enable them to assess whether these are worth their time and attention, and under what conditions they can have a positive influence on children's learning and development. The best way to achieve this is to provide them with research evidence and offer them opportunities to use these tools with children within the frame of safe, pedagogically grounded and supported practice. Pedagogical dialogues, exchange of information, collaborations and learning networks with their colleagues outside their setting will also help with making them feel more confident and prepared to innovate and make changes in their teaching practices. Easy access to digital tools and software and offering a variety of developmentally appropriate resources (e.g. lesson plans, videos with best practices, educational scenarios, technical advice on use) which combine new and traditional pedagogical methods will make them feel supported and competent.

As was shown in this review, social support, collaboration, communities of practice, communities of learning, networks, dialogue, and reflexivity at the individual and collective levels are all crucial dimensions in PD with DT for the ECEC workforce. Shared understandings and peer support are also promoted when a national curriculum or framework which elaborates on the role of DT in ECEC is introduced and implemented. Similarly, theoretical foundations on working with DT are critical and work like an "umbrella" under which all ECEC educators feel protected and secure to take risks and make changes.

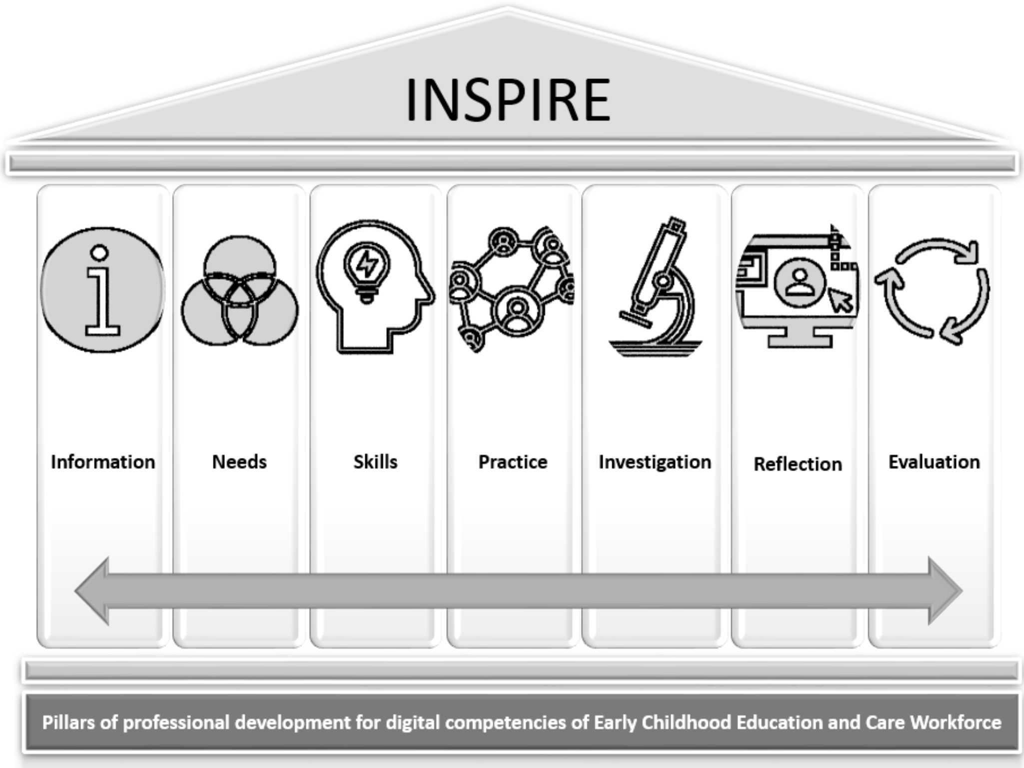
Higher education institutions responsible for initial preparation programmes for ECEC educators also must implement changes and organise their provision in such a way that DC is embedded throughout such courses and it is not seen just as an add-on. Research in academic institutions is pivotal and will further their understanding of what needs to be done. Although many ECEC study programmes in universities already have at least one course which focuses on DT and competencies, our review showed that these courses need improvement. More effort should be placed on increasing hands-on experiences with technology and encouraging the use of DT in work placements. Tertiary education should work in collaboration with ECEC settings, the community and the industry. Pre-service teachers will work with parents and other professionals after they graduate. Understanding the digital needs of the community will be part of their professional role. Universities could consider the continuation of DT training in the first years of employment of their student ECEC graduates to support their confidence and to understand whether their courses are authentic and promote lifelong learning.

The examples of previous successful PD programmes provide a sound basis for implementing effective and sustainable PD on DC. Our findings suggest that effective PD has certain characteristics no matter what the areas of competencies and knowledge. Structural elements are pivotal in designing and delivering effective PD in almost all areas and all educational levels. Future research could examine certain design elements in more detail (e.g. social media; mentors; coaches; flipped PD, etc.) and offer additional insights into the contribution of each element to the effectiveness of PD on DC. Content features relevant to the ECEC workforce should also be examined and updated. Unfortunately, though the need for evaluation in different stages of the PD (e.g. before, during and after) is well-documented (Ahadi et al., 2021[229]; Peterson and Scharber, 2018[230]; Smolin and Lawless, 2011[231]), it is not widely implemented. Self-assessment tools should also be explored and tested.

Guided by the findings of this literature review and considering the evolving nature of DT, we suggest that the seven pillars illustrated in Figure 2**Error! Reference source not found.** the guiding principles for designing effective PD programmes for integrating technologies in ECEC. An effective PD for DC should be based on the pillars of Information, Needs, Skills, Practice, Investigation, Reflection, Evaluation (INSPIRE). As technology develops rapidly, any PD for DC should aim to understand the capability of the ECEC workforce at a personal level first and then if and how they use DT in their work context. Thus, to start with it is important for PD to provide:

- **Information**: PD is designed based on initial information collected from participating ECEC educators, their views, their individual attitudes and beliefs towards technology and their specific and contextual requirements such as resources needed, confidence in the use of certain technologies and identify their specific needs.
- **Needs**: effective PD should seek to identify the needs of the ECEC workforce in three dimensions: structural, content-based and quality (see Figure 1). For DC the needs vary depending, as mentioned above, on participant personal DC and should be context specific to address the DC needs required.
- **Skills**: includes the exact skills, knowledge, awareness, familiarity needed. These are the “lessons” to be learnt (the content) that are shaped by the values and the goals of the ECEC system.
- **Practice**: for everything learnt, they need time and opportunities to practice and implement with children, parents, the community and other professionals.
- **Investigate**: opportunities should be offered to explore other practices or new applications as technology is not static and develops rapidly.
- **Reflection**: this can be a self-assessment, self-evaluation and self-improvement opportunity for teachers. ECEC educators should develop reflective thinking in their pedagogical work.
- **Evaluation**: this stage needs to build on the previous pillar but be broader and include all participants of the PD. Dialogues, collaboration, communities of practice/learning, and networks outside the ECEC setting can all be utilised in this stage. Evaluation needs to be carried out multiple times, not only at the end of a PD initiative. Evaluation findings can then be fed back into the Information and Needs pillars as an ongoing cycle of professional development.

Figure 2. The seven pillars of an effective professional development programme on digital competencies for early childhood education and care professionals



Source: Authors' elaboration.

Rather than suggesting a fixed and fragmented approach to PD that can be outdated by rapid changes in technology, we propose that any training for developing DC amongst the ECEC workforce should be underpinned by these seven pillars.

To conclude, PD should seek to promote educators' autonomy, reflection, creativity and innovation and equally combining technical with pedagogical knowledge and skills is essential. Research needs to examine the DC that might be required for different age groups in terms of developmentally appropriate technology, safety, well-being, play and learning. PD on DC should be oriented by a child-centred pedagogical approach where the child is not any more the "receiver" of information around technology. The use of technology should be seen as a partnership of children and teachers where both guide, scaffold, create, play and learn with and from it. Equally important is that ECEC educators develop DC to be used in other aspects of their work that is not only directly with children, such as administration, record keeping, and communication with parents. ECEC educators should also be able to have skills to promote digital safety with and for the children. Finally, what "technology" is and what is included under this term needs to be clearly explained and any training should provide support and guidance for the ECEC workforce and children to explore, create, and learn with and from digital technology together.

1. Limitations of this review

The aim of this literature review was to describe the current landscape around ECEC professionals' workforce development in DT. A wide range of academic papers, publications, and other professional documents offered a portrait of what has been done and what needs to be done in the future. However, it is acknowledged that there is a strong chance that many more PD efforts have taken place during the period we explored, and they were not located or maybe they have not been reported in a publication. In some cases, research was conducted encompassing both the ECEC professionals and primary school teachers as the focus of the study and the findings reported were general. As much as this literature synthesis has made connections to the repercussions for the ECEC workforce DC development is unique and should be considered carefully by putting the ECEC professionals' needs, strengths, barriers and enablers at the centre of the study. It is also acknowledged that only three languages were used (English, Greek and Norwegian) for exploring the literature and large parts of the world are not included in our review (e.g. Latin America, Asia, Africa and others). Departments of Education were also visited online but the search was not exhaustive. Nevertheless, information gathered is consistent in underlying the need for more PD for ECEC professionals in DT and provides ample details on how these programmes should be designed to be effective and successful. Future research could focus on conceptual frameworks specifically shaped for ECEC and DT; efficient design features, the role of social media, evaluation criteria, self-assessment and reflective tools.

References

Ahadi, A. et al. (2021), "Evaluation of teacher professional learning workshops on the use of technology - A systematic review", *Professional Development in Education*, pp. 1-17, https://doi.org/10.1080/19415257.2021.2011773. [229]

Ahearne, C. et al. (2016), "Touch-screen technology usage in toddlers", *Archives of Disease in Childhood*, Vol. 101/2, pp. 181-183, https://doi.org/10.1136/ARCHDISCHILD-2015-309278. [16]

Ala-Mutka, K., Y. Punie and C. Redecker (2008), *Digital Competence for Lifelong Learning*, Policy Brief, Safeguards in a World of Ambient Intelligence SWAMI View Project, https://doi.org/10.13140/RG.2.2.17285.78567. [21]

Aldhafeeri, F. and P. I. (2016), "Interactions with digital technologies of children from 3 to 6 in Kuwaiti homes", *Educational Futures*, Vol. 7/3, pp. 48-68, https://educationstudies.org.uk/?p=6141. [100]

Aldhafeeri, F., I. Palaiologou and A. Folorunsho (2016), "Integration of digital technologies into play-based pedagogy in Kuwaiti early childhood education: Teachers' views, attitudes and aptitudes", *International Journal of Early Years Education*, Vol. 24/3, pp. 342-360, https://doi.org/10.1080/09669760.2016.1172477. [101]

Aldosemani, T. (2019), "Inservice teachers' perceptions of a professional development plan based on SAMR model: A case study", *TOJET: The Turkish Online Journal of Educational Technology*, Vol. 18/3, pp. 46-53, https://educationstudies.org.uk/?p=6141. [67]

Alelaimat, A., F. Ihmeideh and M. Alkhawaldeh (2020), "Preparing preservice teachers for technology and digital media integration: implications for early childhood teacher education programs", *International Journal of Early Childhood*, Vol. 52/3, pp. 299-3, https://doi.org/10.1007/S13158-020-00276-2. [185]

Alvestad, M. et al. (2017), "Barns fortellinger om lek i barnehagen i en tid preget av moderne medier [Children's stories about play in kindergarten in a time characterised by modern media]", *Norsk Pedagogisk Tidsskrift*, Vol. 101/1, pp. 31-44, https://doi.org/10.18261/issn.1504-2987-2017-01-04. [88]

Anderson, L. and D. Krathwohl (2001), *A Taxonomy for Learning, Teaching and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*, Longman. [52]

Arikan, A., D. Fernie and R. Kantor (2020), "Supporting the professional development of early childhood teachers in Head Start: A case of acquiring technology proficiency", *Elementary Education Online*, Vol. 16/4, pp. 1829-1829, https://doi.org/10.17051/ILKONLINE.2017.342996. [157]

Arnott, L., I. Palaiologou and C. Gray (2019), "An ecological exploration of the internet of toys in early childhood everyday life", in Mascheroni, G. and D. Holloway (eds.), *The Internet of Toys: Practices, Affordances and the Political Economy of Children's Play*, Palgrave Macmillan. [102]

Arnott, L., I. Palaiologou and C. Gray (2019), "Internet of toys across home and early childhood education: Understanding the ecology of the child's social world", *Technology, Pedagogy and Education*, 4, pp. 401-412, https://doi.org/10.1080/1475939X.2019.1656667. [103]

Arnott, L., I. Palaiologou and C. Gray (2018), "Digital devices, internet-enabled toys and digital games: The changing nature of young children's learning ecologies, experiences and pedagogies", *British Journal of Educational Technology*, Vol. 49/5, pp. 803-806, https://doi.org/10.1111/BJET.12676. [11]

Aubrey, C. and S. Dahl (2014), "The confidence and competence in information and communication technologies of practitioners, parents and young children in the Early Years Foundation Stage", *Early Years*, Vol. 34/1, pp. 94-108, https://doi.org/10.1080/09575146.2013.792789. [104]

Australian Department of Education and Workplace Relations (2009), *Belonging, Being & Becoming: The Early Years Learning Framework for Australia*, https://www.acecqa.gov.au/sites/default/files/2018-02/belonging_being_and_becoming_the_early_years_learning_framework_for_australia.pdf. [75]

Balduzzi, L. and A. Lazzari (2015), "Mentoring practices in workplace-based professional preparation: A critical analysis of policy developments in the Italian context", *Early Years*, Vol. 35/2, pp. 124-138, https://doi.org/10.1080/09575146.2015.1022513. [203]

Bartneck, C. and M. Okada (2001), "Robotic user interfaces", *Proceedings of the Human and Computer Conference*. [237]

Bates, C. et al. (2019), "Web-mediated professional development", *Journal of Digital Learning in Teacher Education*, Vol. 35/1, pp. 40-53, https://doi.org/10.1080/21532974.2018.1537817. [222]

Bautista, N. and W. Boone (2015), "Exploring the impact of TeachMETM lab virtual classroom teaching simulation on early childhood education majors' self-efficacy beliefs", *Journal of Science Teacher Education*, Vol. 26/3, pp. 237-262, https://doi.org/10.1007/S10972-014-9418-8. [166]

Baz, E., C. Balçıkanlı and P. Cephe (2018), "Introducing an innovative technology integration model: Echos from ELF pre-service teachers", *Education and Information Technologies*, Vol. 23, pp. 2179-2200, https://doi.org/10.1007/s10639-018-9711-9. [68]

Belo, N. et al. (2016), "Teacher knowledge for using technology to foster early literacy: A literature review", *Computers in Human Behavior*, Vol. 60, pp. 372-383, https://doi.org/10.1016/J.CHB.2016.02.053. [126]

Bers, M. (2019), "Coding as another language: A pedagogical approach for teaching computer science in early childhood", *Journal of Computers in Education*, Vol. 4/6, pp. 499-528, https://doi.org/10.1007/S40692-019-00147-3. [125]

Bers, M. (2018), "Coding and computational thinking in early childhood: The impact of ScratchJr in Europe", *European Journal of STEM Education*, Vol. 3/3, pp. 8-21, https://doi.org/10.20897/ejsteme/3868. [124]

Bers, M. (2017), *Coding as a Playground: Programming and Computational Thinking in the Early Childhood Classroom*, Routledge. [144]

Bird, J. and S. Edwards (2015), "Children learning to use technologies through play: A Digital Play Framework", *British Journal of Educational Technology*, Vol. 46/6, pp. 1149-1160, https://doi.org/10.1111/BJET.12191. [89]

Biswas, S. and Y. Visell (2019), “Emerging material technologies for haptics”, *Advanced Materials Technologies*, Vol. 4/4, pp. 1-30, https://doi.org/10.1002/ADMT.201900042. [20]

Borko, H. (2004), “Professional development and teacher learning: Mapping the terrain”, *Educational Researcher*, Vol. 33/8, pp. 315-330, https://doi.org/10.3102/0013189X033008003. [209]

Bourbour, M. and D. Masoumi (2017), “Practise what you preach: The interactive whiteboard in preschool mathematics education”, *Early Child Development and Care*, Vol. 187/11, pp. 1819-1832, https://doi.org/10.1080/03004430.2016.1192617. [150]

Brown, C., J. Englehardt and H. Mathers (2016), “Examining preservice teachers’ conceptual and practical understandings of adopting iPads into their teaching of young children”, *Teaching and Teacher Education*, Vol. 60, pp. 179-190, https://doi.org/10.1016/J.TATE.2016.08.018. [176]

Brown, C., J. Englehardt and H. Mathers (2016), “Examining preservice teachers’ conceptual and practical understandings of adopting iPads into their teaching of young children”, *Teaching and Teacher Education*, Vol. 60, pp. 179-190, https://doi.org/10.1016/J.TATE.2016.08.018. [182]

Brush, T. et al. (2003), “Integrating technology in a field-based teacher training program: The PT3@ASU project”, *Educational Technology Research and Development*, Vol. 51/1, pp. 57-72, https://doi.org/10.1007/BF02504518. [188]

Bulca, Y., R. Ozdurak and G. Demirhan (2020), “The effects of digital physical exercise videos on the locomotor skill learning of pre-school children”, *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 231-241, https://doi.org/10.1080/1350293X.2020.1716475. [149]

Burnett, C. (2010), “Technology and literacy in early childhood educational settings: A review of research”, *Journal of Early Childhood Literacy*, Vol. 10/3, pp. 247-270, https://doi.org/10.1177/1468798410372154. [127]

Burns, T. and F. Gottschalk (eds.) (2019), *Educating 21st Century Children: Emotional Well-being in the Digital Age*, Educational Research and Innovation, OECD Publishing, Paris, https://doi.org/10.1787/b7f33425-en. [18]

Carpenter, J. and D. Krutka (2015), “Engagement through microblogging: Educator professional development via Twitter”, *Professional Development in Education*, Vol. 41/4, pp. 707-728, https://doi.org/10.1080/19415257.2014.939294. [160]

Carpenter, J. et al. (2020), “What should teacher educators know about technology? Perspectives and self-assessments”, *Teaching and Teacher Education*, Vol. 95, pp. 1-13, https://doi.org/10.1016/J.TATE.2020.103124. [159]

Carpenter, J. et al. (2022), “Exploring the landscape of educator professional activity on Twitter: An analysis of 16 education-related Twitter hashtags”, *Professional Development in Education*, Vol. 48/5, pp. 784-805, https://doi.org/10.1080/19415257.2020.1752287. [216]

Casillas Martín, S., M. Cabezas González and F. García Peñalvo (2019), “Digital competence of early childhood education teachers: Attitude, knowledge and use of ICT”, *European Journal of Teacher Education*, Vol. 43/2, pp. 210-223, https://doi.org/10.1080/02619768.2019.1681393. [60]

Çebi, A. and I. Reisoğlu (2019), “A training activity for improving the digital competences of preservice teachers: The views of pre-service teacher in CEIT and other disciplines”, *Educational Technology Theory and Practice*, Vol. 9/2, pp. 539-565, https://doi.org/10.17943/etku.562663. [169]

Charteris, J., J. Berman and A. Page (2021), "Virtual team professional learning and development for practitioners in education", *Professional Development in Education*, Vol. 47/4, pp. 638-650, https://doi.org/10.1080/19415257.2021.1879215. [218]

Chatzigeorgiadou, S. et al. (2022), "Design Thinking and digital technologies in the exploration of science in early childhood education", in Papadakis, S. and M. Kalogiannakis (eds.), *STEM, Robotics, Mobile Apps in Early Childhood and Primary Education*, Springer. [110]

Chaudron, S. et al. (2015), *Young Children (0-8) and Digital Technology: A Qualitative Exploratory Study Across Seven Countries*, http://publications.jrc.ec.europa.eu/repository/handle/JRC93239. [133]

Chen, J. and C. Chang (2006), "Testing the "whole teacher" approach to professional development: A study of enhancing early childhood teachers' technology proficiency", *Early Childhood Research and Practice*, Vol. 8/1, pp. 1-19. [208]

Cherrington, S. and J. Loveridge (2014), "Using video to promote early childhood teachers' thinking and reflection", *Teaching and Teacher Education*, Vol. 41, pp. 42-51, https://doi.org/10.1016/j.tate.2014.03.004. [219]

Chinese Ministry of Education (2014), *中小学教师信息技术应用能力标准(试行) [Information Technology Application Capability Standard for Primary and Secondary School Teachers (Trial)]*, Beijing, http://www.moe.gov.cn/srcsite/A10/s7034/201405/t20140519_170126.html. [40]

Chova, A. et al. (eds.) (2017), "Development of digital competences in preschool teacher training", *EDULEARN17 Proceedings 9th International Conference on Education and New Learning Technologies July 3rd-5th, 2017*, IATED Academy, https://pubblicazioni.unicam.it/retrieve/handle/11581/407261/101757/EDULEARN17 table of contents.pdf. [200]

Chuang, H. and C. Ho (2011), "An investigation of early childhood teachers' technological pedagogical content knowledge (TPACK) in Taiwan", *Journal of Kirsehir Education Faculty*, Vol. 12/2, pp. 99-117, https://dergipark.org.tr/en/pub/kefad/issue/59495/855162. [71]

Crompton, H. (2017), *ISTE Standards for Educators: A Guide for Teachers and Other Professionals*, Teaching & Learning Faculty Books, https://digitalcommons.odu.edu/teachinglearning_books/24. [87]

Danby, S. et al. (eds.) (2018), "Digital childhoods across contexts and countries", in *Digital Childhoods: Technologies and Children's Everyday Lives*, Springer. [120]

Danniels, E., A. Pyle and C. DeLuca (2020), "The role of technology in supporting classroom assessment in play-based kindergarten", *Teaching and Teacher Education*, Vol. 88, https://doi.org/10.1016/J.TATE.2019.102966. [220]

Dardanou, M. and T. Kofoed (2019), "It is not only about the tools! Professional digital competence", in Gray, C. and I. Palaiologou (eds.), *Early Learning in the Digital Age*, SAGE Publications. [27]

Dardanou, M., I. Palaiologou and S. Kewalramani (2023), "Not just data: Analysing visual narratives of children in research and the quest for "micro-ethical" moments", in Fleer, M. et al. (eds.), *Cultural-historical Digital Methodology: In Times of Change, Innovation and Resilience in the Early Years*, Springer. [42]

Dong, C. (2018), "'Young children nowadays are very smart in ICT'– Preschool teachers' perceptions of ICT use", *International Journal of Early Years Education*, pp. 1-14, https://doi.org/10.1080/09669760.2018.1506318. [196]

Dorouka, P., S. Papadakis and M. Kalogiannakis (2020), "Tablets and apps for promoting robotics, mathematics, STEM education and literacy in early childhood education", *International Journal of Mobile Learning and Organisation*, Vol. 14/2, pp. 255-274, https://doi.org/10.1504/IJMLO.2020.10026334. [140]

Drent, M. and M. Meelissen (2008), "Which factors obstruct or stimulate teacher educators to use ICT innovatively?", *Computers & Education*, Vol. 51, pp. 187-199, https://doi.org/10.1016/j.compedu.2007.05.001. [186]

Dunn, J. et al. (2018), "'It's more funner than doing work': Children's perspectives on using tablet computers in the early years of school", *Early Child Development and Care*, Vol. 188/6, pp. 819-831, https://doi.org/10.1080/03004430.2016.1238824. [111]

EC (2019), *Eurydice 2019: Digital Education at School in Europe*, European Commission, https://doi.org/10.2797/763. [198]

Edwards, S. (2013), "Digital play in the early years: A contextual response to the problem of integrating technologies and play-based pedagogies in the early childhood curriculum", *European Early Childhood Education Research Journal*, Vol. 21/2, pp. 199-212, https://doi.org/10.1080/1350293X.2013.789190. [90]

Edwards, S. and J. Bird (2017), "Observing and assessing young children's digital play in the early years: Using the Digital Play Framework", *Journal of Early Childhood Research*, Vol. 15/2, pp. 158-173, https://doi.org/10.1177/1476718X15579746. [138]

Edwards, S. et al. (2020), "Converged play characteristics for early childhood education: Multi-modal, global-local, and traditional-digital", *Oxford Review of Education*, pp. 1-24, https://doi.org/10.1080/03054985.2020.1750358. [105]

Erstad, O. (2010), "Educating the digital generation", *Nordic Journal of Digital Literacy*, Vol. 5/1, pp. 56-71, https://doi.org/10.18261/ISSN1891-943X-2010-01-05. [4]

Erstad, O., S. Kjällander and S. Jarvela (2021), "Facing the challenges of "digital competence". A Nordic agenda for curriculum development for the 21st century", *Nordic Journal of Digital Literacy*, Vol. 16/2, pp. 77-87, https://doi.org/10.18261/issn.1891-943x-2021-02-04. [39]

Falloon, G. (2020), "From digital literacy to digital competence: The teacher digital competency (TDC) framework", *Educational Technology Research and Development*, Vol. 68/5, pp. 2449-2472, https://doi.org/10.1007/S11423-020-09767-4. [84]

Ferrari, A. (2012), *Digital Competence in Practice: An Analysis of Frameworks*, Joint Research Centre of the European Commission, https://doi.org/10.2791/82116. [51]

Fleer, M. (2020), "Examining the psychological content of digital play through Hedegaard's model of child development", *Learning, Culture and Social Interaction*, Vol. 26, https://doi.org/10.1016/J.LCSI.2018.04.006. [121]

Fleer, M. (2019), "Digitally amplified practices: Beyond binaries and towards a profile of multiple digital coadjuvants", *Mind, Culture, and Activity*, Vol. 26/3, pp. 207-220, https://doi.org/10.1080/10749039.2019.1646289. [12]

FNAE (2018), *National Core Curriculum for Early Childhood Education and Care 2018. Regulations and Guidelines 2018*, Finnish National Agency for Education. [53]

Forbes, A. et al. (2020), "An analysis of the nature of young students' STEM learning in 3D technology-enhanced makerspaces", *Early Education and Development*, Vol. 32/1, pp. 172-187, https://doi.org/10.1080/10409289.2020.1781325. [128]

Fotakopoulou, O. et al. (2020), "A cross-cultural exploration of early childhood educators' beliefs and experiences around the use of touchscreen1 technologies with children under 3 years of age", *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 272-285, https://doi.org/10.1080/1350293X.2020.1735744. [8]

Gaible, E. and M. Burns (2005), *Section 3: Using Technology to Train Teachers: Appropriate Uses of ICT for Teacher Professional Development in Developing Countries*, InfoDev/World Bank, http://www.infodev.org/en/Publication.13.html. [189]

Galindo-Domínguez, H. and M. Bezanilla (2021), "Digital competence in the training of pre-service teachers: Perceptions of students in the degrees of early childhood education and primary education", *Journal of Digital Learning in Teacher Education*, Vol. 37/4, https://doi.org/10.1080/21532974.2021.1934757. [36]

Gentikow, B. (2015), "The role of media in developing literacies and cultural techniques", *Nordic Journal of Digital Literacy*, Vol. 2015/10, pp. 35-52, https://doi.org/10.18261/ISSN1891-943X-2015-JUBILEUMSNUMMER-04. [156]

Gibbons, A. (2010), "Reflections concerning technology: A case for the philosophy of technology in early childhood teacher education and professional development programs", in Izumi-Taylor, S. and S. Blake (eds.), *Technology for Early Childhood Education and Socialization: Developmental Applications and Methodologies*, IGI Global, https://doi.org/10.4018/978-1-60566-784-3.ch001. [145]

Gillen, J. and N. Kucirkova (2018), "Percolating spaces: Creative ways of using digital technologies to connect young children's school and home lives", *British Journal of Educational Technology*, Vol. 49/5, pp. 834-846, https://doi.org/10.1111/BJET.12666. [134]

Gillen, J. et al. (2018), *A Day in the Digital Lives of Children Aged 0-3. Full Report*, DigiLitEY ISCH COST Action 1410 Working Group 1: Digital Literacy in Homes and Communities, https://www.infanciacontemporanea.com/wp-content/uploads/2019/03/03report_finalversion2019.pdf. [93]

Godhe, A. (2019), "Digital literacies or digital competence: Conceptualizations in Nordic curricula", *Media and Communication*, Vol. 7/2, pp. 25-35, https://doi.org/10.17645/MAC.V7I2.1888. [38]

González-Martínez, J., M. Martí and M. Cervera (2019), "Inside a 3D simulation: Realism, dramatism and challenge in the development of students' teacher digital competence", *Australasian Journal of Educational Technology*, Vol. 35/5, pp. 1-14. [80]

Government of Ireland (2021), *Nurturing Skills: The Workforce Plan for Early Learning and Care (ELC) and School-Age Childcare (SAC), 2022-2028*, https://www.gov.ie/en/publication/97056-nurturing-skills-the-workforce-plan-for-early-learning-and-care-elc-and-school-age-childcare-sac-2022-2028/. [202]

Grierson, A., T. Gallagher and R. St Hilaire (2022), "Forging the role of the digital technology coach: Flexibility, responsiveness, and resourcefulness in supporting teacher professional learning", *Professional Development in Education*, pp. 1-16, https://doi.org/10.1080/19415257.2022.2038657. [223]

Guillén-Gámez, F. and J. Mayorga-Fernández (2020), "Quantitative-comparative research on digital competence in students, graduates and professors of faculty education: An analysis with ANOVA", *Education and Information Technologies*, Vol. 25/5, pp. 4157-4174, https://doi.org/10.1007/s10639-020-10160-0. [35]

Gutiérrez Porlán, I., J. Luis and S. Sánchez (2016), “Evaluation and development of digital competence in future primary school teachers at the University of Murcia”, *Journal of New Approaches in Educational Research*, Vol. 5/1, pp. 51-56, https://doi.org/10.7821/NAER.2016.1.152. [81]

Gutiérrez-Castillo, J., J. Cabero-Almenara and L. Estrada-Vidal (2017), “Diseño y validación de un instrumento de evaluación de la competencia digital del estudiante universitario [Design and validation of an instrument of evaluation of the digital competence of the university student]”, *Espacios Magazine*, Vol. 38/10, pp. 1-27, https://idus.us.es/handle/11441/54725. [173]

Hatzigianni, M. et al. (2018), “Using tablets in free play: The implementation of the digital play framework in Greece”, *British Journal of Educational Technology*, Vol. 49/5, pp. 928-942, https://doi.org/10.1111/bjet.12620. [123]

Hatzigianni, M. and I. Kalaitzidis (2018), “Early childhood educators’ attitudes and beliefs around the use of touchscreen technologies by children under three years of age”, *British Journal of Educational Technology*, Vol. 49/5, pp. 883-895, https://doi.org/10.1111/bjet.12649. [94]

Hatzigianni, M. and K. Margetts (2012), ““I am very good at computers”: Young children’s computer use and their computer self-esteem”, *European Early Childhood Education Research Journal*, Vol. 20/1, pp. 3-20, https://doi.org/10.1080/1350293X.2012.650008. [122]

Hatzigianni, M. and K. Margetts (2010), “Observing children when using computers”, *International Research in Early Childhood Education*, Vol. 1/2, pp. 69-86, https://doi.org/10.4225/03/58210d5ff22d5. [153]

Hatzigianni, M. et al. (2020), “Children’s views on making and designing”, *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 286-300, https://doi.org/10.1080/1350293X.2020.1735747. [112]

Hatzigianni, M. et al. (2021), “Young children’s design thinking skills in makerspaces”, *International Journal of Child-Computer Interaction*, Vol. 27, https://doi.org/10.1016/J.IJCCI.2020.100216. [113]

Hennessy, S. and L. London (2013), “Learning from International Experiences with Interactive Whiteboards: The Role of Professional Development in Integrating the Technology”, *OECD Education Working Papers*, No. 89, OECD Publishing, Paris, https://doi.org/10.1787/5k49chbsnmls-en. [206]

Herro, D., S. Hirsch and C. Quigley (2022), “A faculty-in-residence programme: Enacting practice-based professional development in a STEAM-focused middle school”, *Professional Development in Education*, Vol. 48/4, pp. 559-575, https://doi.org/10.1080/19415257.2019.1702579. [225]

Hoel, T. and M. Jernes (2020), “Samtalebasert lesing av bildebok-apper: barnehagelærerversus hotspoter [Dialogue-based reading of picture book apps: The kindergarten teacher versus hotspots]”, *Norsk Pedagogisk Tidsskrift*, Vol. 104/2, pp. 121-133, https://doi.org/10.18261/ISSN.1504-2987-2020-02-04. [151]

Hsin, C., M. Li and C. Tsai (2014), “The influence of young children’s use of technology on their learning: A review”, *Educational Technology & Society*, Vol. 17/4, pp. 85-99. [130]

Hu, X. and N. Yelland (2017), “An investigation of preservice early childhood teachers’ adoption of ICT in a teaching practicum context in Hong Kong”, *Journal of Early Childhood Teacher Education*, Vol. 38/3, pp. 259-274, https://doi.org/10.1080/10901027.2017.133566. [177]

Ilomäki, L., A. Kantosalo and M. Lakkala (2011), “What is digital competence?”, https://helda.helsinki.fi/bitstream/handle/10138/154423/Ilom_ki_etal_2011_What_is_digital_competence.pdf. [22]

Ilomäki, L. et al. (2016), “Digital competence - An emergent boundary concept for policy and educational research”, *Education and Information Technologies*, Vol. 21/3, pp. 655-679, https://doi.org/10.1007/S10639-014-9346-4. [25]

Instefjord, E. and E. Munthe (2017), “Educating digitally competent teachers: A study of integration of professional digital competence in teacher education”, *Teaching and Teacher Education*, Vol. 67, pp. 37-45, https://doi.org/10.1016/J.TATE.2017.05.016. [174]

INTEF (2017), *The Common Digital Competence Framework for Teachers*, Instituto Nacional de Tecnologías Educativas y de Formación del Profesorado, http://aprende.educalab.es. [79]

Irish Department of Education (2022), *Digital Strategy for Schools to 2027*, https://www.gov.ie/en/publication/69fb88-digital-strategy-for-schools/. [201]

ISTE (2017), *ISTE Standards for Educators*, International Society for Technology in Education, https://www.iste.org/standards/iste-standards-for-teachers. [85]

Jack, C. and S. Higgins (2019), “What is educational technology and how is it being used to support teaching and learning in the early years?”, *International Journal of Early Years Education*, Vol. 27/3, pp. 222-23, https://doi.org/10.1080/09669760.2018.1504754. [106]

Jacobsen, M., S. Friesen and B. Brown (2018), “Teachers’ professional learning focused on designs for early learners and technology”, in Polly, D. et al. (eds.), *Innovative Practices in Teacher Preparation and Graduate-Level Teacher Education Programs*, https://doi.org/10.4018/978-1-5225-3068-8.ch022. [210]

Janssen, J. et al. (2013), “Experts’ views on digital competence: Commonalities and differences”, *Computers & Education*, Vol. 68, pp. 473-481, https://doi.org/10.1016/J.COMPEDU.2013.06.008. [5]

Jernes, M. and K. Engelsen (2012), “Stille kamp om makten: En studie av barns interaksjon i digital kontekst i barnehagen barnehagen [Quiet struggle for power: A study of children’s interactions in a digital kindergarten context]”, *Nordic Studies in Education*, Vol. 32/3-4, pp. 281-296, https://doi.org/10.18261/ISSN1891-5949-2012-03-04-08. [95]

Johnston, K., F. Hadley and M. Waniganayake (2020), “Practitioner inquiry as a professional learning strategy to support technology integration in early learning centres: Building understanding through Rogoff’s planes of analysis”, *Professional Development in Education*, Vol. 46/1, pp. 49-64, https://doi.org/10.1080/19415257.2019.1647871. [91]

Johnston, K., K. Highfield and F. Hadley (2018), “Supporting young children as digital citizens: The importance of shared understandings of technology to support integration in play-based learning”, *British Journal of Educational Technology*, Vol. 49/5, pp. 896-910, https://doi.org/10.1111/BJET.12664. [114]

Kay, R. (2006), “Evaluating strategies used to incorporate technology into preservice education: A review of the literature”, *Journal of Research on Technology in Education*, Vol. 38/4, pp. 383-408, https://doi.org/10.1080/15391523.2006.10782466. [187]

Kelentrić, M., K. Helland and A. Arstorp (2017), *Professional Digital Competence Framework for Teachers*, Norwegian Centre for ICT, https://www.udir.no/contentassets/081d3aef2e4747b096387aba163691e4/pfdk-framework.pdf. [54]

Kewalramani, S. and S. Havu-Nuutinen (2019), "Preschool teachers' beliefs and pedagogical practices in the integration of technology: A case for engaging young children in scientific inquiry", *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 15/12, p. em1784, https://doi.org/10.29333/EJMSTE/109949. [9]

Kewalramani, S., G. Kidman and I. Palaiologou (2021), "Using artificial intelligence (AI)-interfaced robotic toys in early childhood settings: A case for children's inquiry literacy", *European Early Childhood Education Research Journal*, Vol. 29/5, pp. 652-668, https://doi.org/10.1080/1350293X.2021.1968458. [44]

Kewalramani, S. et al. (2020), "The integration of the internet of toys in early childhood education: A platform for multi-layered interactions", *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 197-213, https://doi.org/10.1080/1350293X.2020.1735738. [43]

Kewalramani, S., I. Palaiologou and M. Dardanou (2023), *The Integration of Internet of Toys in Early Childhood Education: Research from Australia, England, and Norway*, Routledge, https://doi.org/10.4324/9781003185840. [31]

Kewalramani, S., I. Palaiologou and M. Dardanou (2020), "Children's engineering design thinking processes: The magic of the ROBOTS and the power of BLOCKS (Electronics)", *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 16/3, p. em1830, https://doi.org/10.29333/EJMSTE/113247. [115]

Kewalramani, S. et al. (2021), "Using robotic toys in early childhood education to support children's social and emotional competencies", *Australasian Journal of Early Childhood*, Vol. 46/4, pp. 355-369, https://doi.org/10.1177/18369391211056668. [116]

Kleiner, B., N. Thomas and L. Lewis (2007), *Educational Technology in Teacher Education Programs for Initial Licensure Statistical Analysis Report*, http://nces.ed.gov. [167]

Koehler, M., P. Mishra and W. Cain (2013), "What is technological pedagogical content knowledge (TPACK)?", *Journal of Education*, Vol. 193/3, pp. 13-19, https://www.jstor.org/stable/24636917. [59]

Koltay, T. (2011), "The media and the literacies: Media literacy, information literacy, digital literacy", *Media, Culture & Society*, Vol. 33/2, pp. 211-221, https://doi.org/10.1177/0163443710393382. [154]

Komis, V. et al. (2021), "Smart toys in early childhood and primary education: A systematic review of technological and educational affordances", *Applied Sciences*, Vol. 11/18, p. 8653, https://doi.org/10.3390/APP11188653. [137]

Kopetz, H. (2011), *Real-Time Systems (2nd ed.)*, Springer US, https://doi.org/10.1007/978-1-4419-8237-7. [233]

Kozma, R. (ed.) (2003), *Technology, Innovation, and Educational Change: A Global Perspective*, International Society for Technology in Education, Eugene, OR. [207]

Kress, G. (2010), *Multimodality: A Social Semiotic Approach to Contemporary Communication*, Routledge. [57]

Krumsvik, R. (2014), "Teacher educators' digital competence", *Scandinavian Journal of Educational Research*, Vol. 58/3, pp. 269-280, https://doi.org/10.1080/00313831.2012.726273. [61]

Krumsvik, R. (2011), "Digital competence in the Norwegian teacher education and schools", *Högre Utbildning*, Vol. 1/1, pp. 39-51, https://hogreutbildning.se/index.php/hu/article/view/874. [175]

Kucirkova, N. et al. (2019), “Systematic review of young children’s writing on screen: What do we know and what do we need to know”, *Literacy*, Vol. 53/4, pp. 216-225, https://doi.org/10.1111/LIT.12173. [129]

Lafton, T. (2019), “Becoming clowns: How do digital technologies contribute to young children’s play?”, *Contemporary Issues in Early Childhood*, Vol. 22/3, pp. 221-231, https://doi.org/10.1177/1463949119864207. [96]

Lakkala, M. and L. Ilomäki (2015), “A case study of developing ICT-supported pedagogy through a collegial practice transfer process”, *Computers & Education*, Vol. 90, pp. 1-12, https://doi.org/10.1016/J.COMPEDU.2015.09.001. [41]

Lauricella, A., E. Wartella and V. Rideout (2015), “Young children’s screen time: The complex role of parent and child factors”, *Journal of Applied Developmental Psychology*, Vol. 36, pp. 11-17, https://doi.org/10.1016/J.APPDEV.2014.12.001. [17]

Lindeman, S., M. Svensson and A. Enochsson (2021), “Digitalisation in early childhood education: A domestication theoretical perspective on teachers’ experiences”, *Education and Information Technologies*, Vol. 26/4, pp. 4879-4903, https://doi.org/10.1007/s10639-021-10501-7. [28]

Ling, L. et al. (2022), “The use of Internet of Things devices in early childhood education: A systematic review”, *Education and Information Technologies*, Vol. 27/5, pp. 6333-6352, https://doi.org/10.1007/S10639-021-10872-X. [234]

Ling, L. et al. (2021), “Toward a conceptualization of the internet of toys”, *Australasian Journal of Early Childhood*, Vol. 46/3, pp. 249-262, https://doi.org/10.1177/18369391211007327. [58]

Liu, X., E. Toki and J. Pange (2014), “The use of ICT in preschool education in Greece and China: A comparative study”, *Procedia - Social and Behavioral Sciences*, Vol. 112, pp. 1167-1176, https://doi.org/10.1016/J.SBSPRO.2014.01.1281. [195]

Ljunggren, Å. (2016), “Multilingual affordances in a Swedish preschool: An action research project”, *Early Childhood Education Journal*, Vol. 44/6, pp. 605-612, https://doi.org/10.1007/S10643-015-0749-7. [97]

Lundqvist, K., K. Baker and S. Williams (2008), “An ontological approach to competency management”, *Proceedings of ILearn 2007*, pp. 1-4, http://www.eife-l.org/publications/proceedings/ilf07/Contribution110.doc.pdf/view. [26]

Luo, W., I. Berson and M. Berson (2021), “Integration of digital technology into an early childhood teacher preparation program in China”, *Early Childhood Education Journal*, Vol. 49/6, pp. 1165-1175, https://doi.org/10.1007/S10643-020-01115-8. [33]

Luo, W. et al. (2021), “Are early childhood teachers ready for digital transformation of instruction in Mainland China? A systematic literature review”, *Children and Youth Services Review*, Vol. 120, pp. 1-15, https://doi.org/10.1016/J.CHILDYOUTH.2020.105718. [34]

Lux, N., A. Bangert and D. Whittier (2012), “The development of an instrument to assess preservice teacher’s technological pedagogical content knowledge”, *Journal of Educational Computing Research*, Vol. 45/4, pp. 415-431, https://doi.org/10.2190/EC.45.4.C. [184]

Lympou, V. (2018), “Στάσεις και απόψεις εκπαιδευτικών της Πρωτοβάθμιας Εκπαίδευσης για το πρόγραμμα επιμόρφωσης Β1 επιπέδου στις Τ.Π.Ε. [Attitudes and beliefs of primary teachers about the B1 level of professional development in ICT in education]”, University of Macedonia, http://dspace.lib.uom.gr/handle/2159/22010. [190]

Madanipour, P. and C. Cohrssen (2020), "Augmented reality as a form of digital technology in early childhood education", *Australasian Journal of Early Childhood*, Vol. 45/1, pp. 5-13, https://doi.org/10.1177/1836939119885311. [139]

Mantilla, A. and S. Edwards (2019), "Digital technology use by and with young children: A systematic review for the Statement on Young Children and Digital Technologies", *Australasian Journal of Early Childhood*, Vol. 44/2, pp. 182-195, https://doi.org/10.1177/1836939119832744. [131]

Marsh, J. et al. (2018), "Play and creativity in young children's use of apps", *British Journal of Educational Technology*, Vol. 49/5, pp. 870-882, https://doi.org/10.1111/BJET.12622. [92]

Marsh, J. et al. (2019), "Makerspaces in early childhood education: Principles of pedagogy and practice", *Mind, Culture, and Activity*, Vol. 26/3, pp. 221-233, https://doi.org/10.1080/10749039.2019.1655651. [13]

Martin, A. (2006), "A European framework for digital literacy", *Nordic Journal of Digital Literacy*, Vol. 1/2, pp. 151-161, https://doi.org/10.18261/ISSN1891-943X-2006-02-06. [73]

Masoumi, D. (2021), "Situating ICT in early childhood teacher education", *Education and Information Technologies*, Vol. 26/3, pp. 3009-3026, https://doi.org/10.1007/S10639-020-10399-7. [37]

McGarr, O. and A. McDonagh (2019), *Digital Competence in Teacher Education, Output 1 of the Erasmus+ Funded Developing Student Teachers' Digital Competence (DICTE) Project*. [155]

McGlynn-Stewart, M. et al. (2017), "Inclusive teaching with digital technology: Supporting literacy learning in play-based kindergartens", *LEARNing Landscapes*, Vol. 11/1, pp. 199-216, https://doi.org/10.36510/LEARNLAND.V11I1.932. [108]

Mertala, P. (2021), "The pedagogy of multiliteracies as a code breaker: A suggestion for a transversal approach to computing education in basic education", *British Journal of Educational Technology*, Vol. 52/6, pp. 2227-2241, https://doi.org/10.1111/BJET.13125. [47]

Miller, J. et al. (2017), "Looking beyond swiping and tapping: Review of design and methodologies for researching young children's use of digital technologies", *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, Vol. 11/3, p. 6, https://doi.org/10.5817/CP2017-3-6. [132]

Miorandi, D. et al. (2012), "Internet of things: Vision, applications and research challenges", *Ad Hoc Networks*, Vol. 10/7, pp. 1497-1516, https://doi.org/10.1016/J.ADHOC.2012.02.016. [235]

Mishra, P. and M. Koehler (2006), "Technological pedagogical content knowledge: A framework for teacher knowledge", *Teachers College Record*, Vol. 6, pp. 1017-1054, https://doi.org/10.1111/j.1467-9620.2006.00684.x. [62]

Mukan, N. and M. Noskova (2019), "Teachers' digital competence development: Estonian state policy in the field", *Comparative Professional Pedagogy*, Vol. 9/1, pp. 26-32, https://doi.org/10.2478/rpp-2019-0003. [199]

Muñoz-Carril, P., M. González-Sanmamed and E. Fuentes-Abeledo (2020), "Use of blogs for prospective early childhood teachers", *Educacion XX1*, Vol. 23/1, pp. 274-273, https://doi.org/10.5944/EDUCXX1.23768. [228]

Murcia, K., C. Campbell and G. Aranda (2018), "Trends in early childhood education practice and professional learning with digital technologies", *Pedagogika*, Vol. 68/3, https://doi.org/10.14712/23362189.2018.858. [178]

NAEYC/Fred Rogers Center (n.d.), "Technology and interactive media as tools in early childhood programs serving children from birth through age 8", National Association for the Education of Young Children, https://www.naeyc.org/sites/default/files/globally-shared/downloads/PDFs/resources/position-statements/ps_technology.pdf. [171]

NCTI/CITEd (2006), *Tools for Evaluation: Assistive Technology Tools Kits*, National Center for Technology Innovation and Center for Implementing Technology in Education, https://www.ldonline.org/ld-topics/assistive-technology/tools-evaluation-assistive-technology-tools-kits. [213]

Ndongfack, M. (2015), "TPACK constructs: A sustainable pathway for teachers professional development on technology adoption", *Creative Education*, Vol. 6/16, pp. 1697-1709, https://doi.org/10.4236/CE.2015.616171. [70]

New Zealand Ministry of Education (2019), *Digital Technologies and Hangarau Matihiko learning – Education in New Zealand*, https://www.education.govt.nz/our-work/changes-in-education/digital-technologies-and-hangarau-matihiko-learning/. [205]

Newman, T. (2008), "A review of digital literacy in 3-16-year-olds: Evidence, developmental models, and recommendations", https://kipdf.com/a-review-of-digital-literacy-in-3-16-year-olds-evidence-developmental-models-and_5aaf5c161723dd349c80a11b.html. [74]

Ng, W. (2012), "Can we teach digital natives digital literacy?", *Computers & Education*, Vol. 59/3, pp. 1065-1078, https://doi.org/10.1016/J.COMPEDU.2012.04.016. [6]

Niess, M. (2005), "Preparing teachers to teach science and mathematics with technology: Developing a technology pedagogical content knowledge", *Teaching and Teacher Education*, Vol. 21/5, pp. 509-523, https://doi.org/10.1016/j.tate.2005.03.006. [180]

Norwegian Ministry of Education and Research (2012), *Forskriftomrammeplan for Barnehagelæreutdanning [Regulations on Framework for Early Childhood Education Studies]*, https://lovdata.no/dokument/SF/forskrift/2012-06-04-475. [170]

Novella-García, C. and A. Cloquell-Lozano (2021), "The ethical dimension of digital competence in teacher training", *Education and Information Technologies*, Vol. 26/3, pp. 3529-3541, https://doi.org/10.1007/s10639-021-10436-z. [29]

O'Connor, J. and O. Fotakopoulou (2016), "A threat to childhood innocence or the future of learning? Parents' perspectives on the use of touch-screen technology by 0–3 year-olds in the UK", *Contemporary Issues in Early Childhood*, Vol. 17/2, pp. 235-247, https://doi.org/10.1177/1463949116647290. [99]

O'Connor, J. et al. (2019), "Parents perspectives on the use of touchscreen technology by 0-3 year olds in the UK, Sweden, Australia and Greece", in Gray, C. and I. Palaiologou (eds.), *Early Learning in the Digital Age*, Sage Publications. [98]

OECD (2022), "Early childhood education and care workforce development: A foundation for process quality", *OECD Education Policy Perspectives*, No. 54, OECD Publishing, Paris, https://doi.org/10.1787/e012efc0-en. [1]

OECD (2022), "Quality assurance and improvement in the early education and care sector", *OECD Education Policy Perspectives*, No. 55, OECD Publishing, Paris, https://doi.org/10.1787/774688bf-en. [2]

Ottenbreit-Leftwich, A. et al. (2010), "Teacher value beliefs associated with using technology: Addressing professional and student needs", *Computers and Education*, Vol. 55/3, pp. 1321-1335, https://doi.org/10.1016/J.COMPEDU.2010.06.002. [164]

Ottenbreit-Leftwich, A. et al. (2010), "Teacher value beliefs associated with using technology: Addressing professional and student needs", *Computers and Education*, Vol. 55/3, pp. 1321-1335, https://doi.org/10.1016/J.COMPEDU.2010.06.002. [181]

Page, M. et al. (2021), "The PRISMA 2020 statement: An updated guideline for reporting systematic reviews", *International Journal of Surgery*, Vol. 10/89, pp. 1-11, https://doi.org/10.1136/BMJ.N71. [24]

Palaiologou, I. (2016), "Children under five and digital technologies: Implications for early years pedagogy", *European Early Childhood Education Research Journal*, Vol. 24/1, pp. 5-24, https://doi.org/10.1080/1350293X.2014.929876. [19]

Palaiologou, I. (2016), "Teachers' dispositions towards the role of digital devices in play-based pedagogy in early childhood education", *Early Years*, Vol. 36/3, pp. 305-321, https://doi.org/10.1080/09575146.2016.1174816. [10]

Palaiologou, I., S. Kewalramani and M. Dardanou (2021), "Make-believe play with Internet of Toys: A case for multimodal playscapes", *British Journal of Educational Research*, Vol. 52, pp. 2100-2117, https://doi.org/10.1111/bjet.13110. [45]

Papadakis, S. and M. Kalogiannakis (2017), "Mobile educational applications for children. What educators and parents need to know", *International Journal of Mobile Learning and Organisation*, Vol. 11/3, pp. 256-277, https://doi.org/10.1504/IJMLO.2017.10003925. [141]

Parette, H. et al. (2013), "Technology user groups and early childhood education: A preliminary study", *Early Childhood Education Journal*, Vol. 41/3, pp. 171-179, https://www.learntechlib.org/p/114157/. [211]

Parette, H. et al. (2008), "Using Microsoft® PowerPointTM to support emergent literacy skill development for young children at-risk or who have disabilities", *Early Childhood Education Journal*, Vol. 36/3, pp. 233-239, https://www.academia.edu/20206479/Using_Microsoft_PowerPoint_to_Support_Emergent_Literacy_Skill_Development_for_Young_Children_At_Risk_or_Who_Have_Disabilities. [214]

Parette, H. et al. (2007), "Developing competence in assistive technology implementation through user groups", *Exceptional Children*, Vol. 40/2, pp. 28-34, https://doi.org/10.1177/004005990704000204. [212]

Parette, H., A. Quesenberry and C. Blum (2010), "Missing the boat with technology usage in early childhood settings: A 21st century view of developmentally appropriate practice", *Early Childhood Education Journal*, Vol. 37/5, pp. 335-343, https://doi.org/10.1007/S10643-009-0352-X. [48]

Park, E. and J. Hargis (2018), "New perspective on TPACK framework in the context of early childhood education: The "A" stands for affective", *International Journal for the Scholarship of Teaching and Learning*, Vol. 12/2, https://doi.org/10.20429/ijsotl.2018.120217. [63]

Peterson, L. and C. Scharber (2018), "Learning about makerspaces: Professional development with K-12 inservice educators", *Journal of Digital Learning in Teacher Education*, Vol. 34/1, pp. 43-52, https://doi.org/10.1080/21532974.2017.1387833. [230]

Pickering, L. and E. Walsh (2011), "Using videoconferencing technology to enhance classroom observation methodology for the instruction of preservice early childhood professionals", *Journal of Digital Learning in Teacher Education*, Vol. 27/3, pp. 99-108. [221]

Plowman, L. (2016), "Rethinking context: Digital technologies and children's everyday lives Rethinking context: Digital technologies and children's everyday lives", *Children's Geographies*, Vol. 14/2, pp. 190-202, https://doi.org/10.1080/14733285.2015.1127326. [135]

Plowman, L. and C. Stephen (2003), "A 'benign addition'? Research on ICT and pre-school children", *Journal of Computer Assisted Learning*, Vol. 19/2, pp. 149-164, https://doi.org/10.1046/J.0266-4909.2003.00016.X. [117]

Polly, D. et al. (2010), "Evidence of impact: Transforming teacher education with preparing tomorrow's teachers to teach with technology (PT3) grants", *Teaching and Teacher Education*, Vol. 26/4, pp. 863-870, https://doi.org/10.1016/J.TATE.2009.10.024. [158]

Pölzl-Stefanec, E. (2021), "Challenges and barriers to Austrian early childhood educators' participation in online professional development programmes", *British Journal of Educational Technology*, Vol. 52/6, pp. 2192-2208, https://doi.org/10.1111/BJET.13124. [161]

Puentedura, R. (2006), "Transformation, technology, and education part 1: A model for technology and transformation", http://hippasus.com/resources/tte/puentedura_tte.pdf. [66]

Punie, Y. (ed.) (2017), *European Framework for the Digital Competence of Educators: DigCompEdu*, EUR 28775 EN, Publications Office of the European Union, Luxembourg, https://doi.org/10.2760/159770. [172]

Pusey, P. and W. Sadera (2012), "Cyberethics, cybersafety, and cybersecurity: Preservice teacher knowledge, preparedness, and the need for teacher education to make a difference", *Journal of Digital Learning in Teacher Education*, Vol. 28/2, pp. 82-88. [232]

Redecker, C. and Y. Punie (2017), *European Framework for the Digital Competence of Educators: DigCompEdu*, Joint Research Centre, European Commission, https://doi.org/10.2760/159770. [23]

Reinertsen, A. et al. (2020), "Følgeevaluering av Oslo og Viken modellen i Regional ordning for barnehagebasert kompetanseutvikling (REKOMP), 2019-20 [Follow-up evaluation of the Oslo and Viken model in the Regional scheme for kindergarten-based competence development]", https://openarchive.usn.no/usn-xmlui/bitstream/handle/11250/2683637/2020_57_Reinertsen_Skriftserie.pdf?sequence=1&isAllowed=y. [197]

Romeo, G., M. Lloyd and T. Downes (2012), "Teaching Teachers for the Future (TTF): Building the ICT in education capacity of the next generation of teachers in Australia", *Australasian Journal of Educational Technology*, Vol. 28/6, pp. 949-964, https://doi.org/10.14742/AJET.804. [179]

Romero-Tena, R. et al. (2020), "The challenge of initial training for early childhood teachers. A cross sectional study of their digital competences", *Sustainability*, Vol. 12/11, p. 4782. [83]

Rosen, D. and C. Jaruszewicz (2009), "Developmentally appropriate technology use and early childhood teacher education", *Journal of Early Childhood Teacher Education*, Vol. 30/2, pp. 162-171, https://doi.org/10.1080/10901020902886511. [49]

Sánchez-Carracedo, F. et al. (2021), "Education for sustainable development in Spanish university education degrees", *Sustainability*, Vol. 13/3, p. 1467, https://doi.org/10.3390/SU13031467. [56]

Schriever, V. (2021), "Early childhood teachers' management of their changing roles regarding digital technologies in kindergarten: A grounded theory study", *Australasian Journal of Early Childhood*, Vol. 46/1, pp. 32-49, https://doi.org/10.1177/1836939120979065. [72]

Selwyn, N. (2010), "Looking beyond learning: Notes towards the critical study of educational technology", *Journal of Computer Assisted Learning*, Vol. 26/1, pp. 65-73, https://doi.org/10.1111/J.1365-2729.2009.00338.X. [152]

Shulman, L. (1986), "Those who understand: Knowledge growth in teaching", *Educational Researcher*, Vol. 15/2, pp. 4-14, https://doi.org/10.3102/0013189X015002004. [69]

Skantz Åberg, E. et al. (2022), "Teachers' professional digital competence: An overview of conceptualisations in the literature", *Cogent Education*, Vol. 9/1, pp. 1-23, https://doi.org/10.1080/2331186X.2022.2063224. [76]

Skantz Åberg, E., A. Lantz-Andersson and N. Pramling (2014), "'Once upon a time there was a mouse': Children's technology-mediated storytelling in preschool class", *Early Child Development and Care*, Vol. 184/11, pp. 1583-1598, https://doi.org/10.1080/03004430.2013.867342. [148]

Smolin, L. and K. Lawless (2011), "Evaluation across contexts: Evaluating the impact of technology integration professional development partnerships", *Journal of Digital Learning in Teacher Education*, Vol. 27/3, pp. 92-98. [231]

Spilker, M., F. Prinsen and M. Kalz (2020), "Valuing technology-enhanced academic conferences for continuing professional development: A systematic literature review", *Professional Development in Education*, Vol. 46/3, pp. 482-499, https://doi.org/10.1080/19415257.2019.1629614. [227]

Stephen, C. and S. Edwards (2018), *Young Children Playing and Learning in a Digital Age: A Cultural and Critical Perspective*, Routledge, https://www.routledge.com/Young-Children-Playing-and-Learning-in-a-Digital-Age-a-Cultural-and-Critical/Stephen-Edwards/p/book/9781138654693. [146]

Stephen, C. and L. Plowman (2003), "Information and communication technologies in pre-school settings: A review of the literature", *International Journal of Early Years Education*, Vol. 11/3, pp. 223-234, https://doi.org/10.1080/0966976032000147343. [118]

Straker, L. et al. (2022), "Towards a transdisciplinary approach to evidence-based decision making regarding digital technology use with, by and for children", *Digital Child Working Paper*, No. 2022-01, https://doi.org/10.26187/b04b-1j97. [162]

Sulaymani, O., M. Fleer and D. Chapman (2018), "Understanding children's motives when using iPads in Saudi classrooms: Is it for play or for learning?", *International Journal of Early Years Education*, Vol. 26/4, pp. 340-353, https://doi.org/10.1080/09669760.2018.1454303. [107]

Sullivan, A. and M. Bers (2016), "Robotics in the early childhood classroom: Learning outcomes from an 8-week robotics curriculum in pre-kindergarten through second grade", *International Journal of Technology and Design Education*, Vol. 26/1, pp. 3-20, https://doi.org/10.1007/s10798-015-9304-5. [14]

Sung, K. (2015), "A case study on a flipped classroom in an EFL content course", *Multimedia-Assisted Language Learning*, Vol. 18/2, pp. 159-187, https://doi.org/10.15702/MALL.2015.18.2.159. [236]

Symenonidis, S., S. Goumas and K. Savvidou (2014), "Τρία χρόνια μετά την επιμόρφωση β επιπέδου: Οι εκπαιδευτικοί κάνουν χρήση και αξιοποιούν τις Τεχνολογίες Πληροφορίας & Επικοινωνιών (Τ.Π.Ε) στην εκπαιδευτική- διδακτική διαδικασία;", *Η περίπτωση του νομού Καβάλας [E-Journal of Science & Technology (e-JST)]*, Vol. 2/9, pp. 1-10, http://e-jst.teiath.gr. [191]

Taddeo, G. et al. (2016), *MENTEP Mentoring Technology-Enhanged Pedagogy. Certification of Teachers' Digital Competence - Current Approaches and Future Opportunities*, http://mentep.eun.org/documents/2390578/2452293/MENTEP_D6+1.pdf/e9982840-f226-4b68-bebd-4fefeb67004e. [204]

Tan, L. et al. (2019), "Examining pre-service teachers' knowledge of teaching multimodal literacies: A validation of a TPACK survey", *Educational Media International*, Vol. 56/4, pp. 285-99, https://doi.org/10.1080/09523987.2019.1681110. [64]

Thorpe, K. et al. (2015), "Digital access to knowledge in the preschool classroom: Reports from Australia", *Early Childhood Research Quarterly*, Vol. 32, pp. 174-182, https://doi.org/10.1016/J.ECRESQ.2015.04.001. [78]

Tømte, C. (2015), "Educating teachers for the new millennium?", *Nordic Journal of Digital Literacy*, Vol. 8/1-02, pp. 74-88, https://doi.org/10.18261/ISSN1891-943X-2013-01-02-05. [46]

Tondeur, J. et al. (2017), "Developing a validated instrument to measure preservice teachers' ICT competencies: Meeting the demands of the 21st century", *British Journal of Educational Technology*, Vol. 48/2, pp. 462-472, https://doi.org/10.1111/BJET.12380. [168]

Triantafyllou, M. (2018), "Αξιολόγηση της Επιμόρφωσης Β΄ Επιπέδου των δασκάλων μέσα από τις απόψεις και τις αντιλήψεις τους σχετικά με την εφαρμογή και την αξιοποίηση των ΤΠΕ στη διδακτική πράξη [Evaluation of in-service training of teachers the utilization and application of IC]", Open University Greece, https://apothesis.eap.gr/handle/repo/39950. [192]

Trilling, B. and C. Fadel (2009), *21st Century Skills, Enhanced Edition: Learning for Life in Our Times*, Jossey-Bass, A Wiley Imprint, https://www.wiley.com/en-us/21st+Century+Skills%3A+Learning+for+Life+in+Our+Times-p-9780470553916. [7]

Trust, T. and E. Pektas (2018), "Using the ADDIE model and universal design for learning principles to develop an open online course for teacher professional development", *Journal of Digital Learning in Teacher Education*, Vol. 34/4, pp. 219-233, https://doi.org/10.1080/21532974.2018.1494521. [217]

Tveiterås, N. and S. Madsen (2022), "From tools to complexity? A systematic literature analysis of digital competence among pre-service teachers in Norway", in Tomczyk, Ł. and L. Fedeli (eds.), *Digital Literacy for Teachers*, Springer. [165]

UN (2020), *UN 2030 Agenda: The Sustainable Development Goals Report 2020*, United Nations, https://bit.ly/3f3FnRq. [55]

Undheim, M. (2021), "Children and teachers engaging together with digital technology in early childhood education and care institutions: A literature review", *European Early Childhood Education Research Journal*, Vol. 30/3, pp. 472-489. [147]

Undheim, M. (2020), ""We need sound too!" Children and teachers creating multimodal digital stories together", *Nordic Journal of Digital Literacy*, Vol. 15/3, pp. 165-177, https://doi.org/10.18261/ISSN.1891-943X-2020-03-03. [136]

Undheim, M. and M. Jernes (2020), "Teacher's pedagogical strategies when creating digital stories with young children", *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 256-271, https://doi.org/10.1080/1350293X.2020.1735743. [143]

UNESCO (2018), *UNESCO ICT Competency Framework for Teachers*, United Nations Educational, Scientific and Cultural Organization, https://unesdoc.unesco.org/ark:/48223/pf0000265721. [77]

UNESCO (2011), *ICT Competency Standards for Teachers (Version 2)*, United Nations Educational, Scientific and Cultural Organization, https://www.schoolnet.org.za/wp-content/uploads/Documents/ICT-CFT_ver2_5_July1.pdf. [86]

Urrea-Solano, M. et al. (2021), "The learning of e-sustainability competences: A comparative study between future early childhood and primary school teachers", *Education Sciences*, Vol. 11/10, p. 644, https://doi.org/10.3390/educsci11100644. [30]

Vartiainen, H., T. Leinonen and S. Nissinen (2019), "Connected learning with media tools in kindergarten: An illustrative case", *Educational Media International*, Vol. 56/3, pp. 233-249, https://doi.org/10.1080/09523987.2019.1669877. [142]

Venkatesh, V. et al. (2003), "User acceptance of information technology: Toward a unified view", *MIS Quarterly*, Vol. 27/3, p. 478, https://www.academia.edu/13995368/User_Acceptance_of_Information_Technology_Toward_a_Unified_View. [183]

Victorian Department of Education and Training (2021), *School Readiness Funding Menu - Tile View*, https://www.education.vic.gov.au/childhood/providers/funding/Pages/SRFmenu_tiles.aspx. [163]

Vidal-Hall, C., R. Flewitt and D. Wyse (2020), "Early childhood practitioner beliefs about digital media: Integrating technology into a child-centred classroom environment", *European Early Childhood Education Research Journal*, Vol. 28/2, pp. 167-181, https://doi.org/10.1080/1350293X.2020.1735727. [109]

Voogt, J. and S. McKenney (2017), "TPACK in teacher education: Are we preparing teachers to use technology for early literacy?", *Technology, Pedagogy and Education*, Vol. 26/1, pp. 69-83, https://doi.org/10.1080/1475939X.2016.1174730. [65]

Wang, Y., J. Lavonen and K. Tirri (2018), "Aims for learning 21st century competencies in national primary science curricula in China and Finland", *Eurasia Journal of Mathematics, Science and Technology Education*, Vol. 14/6, pp. 2081-2095, https://doi.org/10.29333/ejmste/86363. [50]

WEF (2016), *New Vision for Education: Fostering Social and Emotional Learning through Technology*, World Economic Forum, https://www3.weforum.org/docs/WEF_New_Vision_for_Education.pdf. [3]

Xafakos, E. et al. (2016), "Στάσεις των εκπαιδευτικών Πρωτοβάθμιας Εκπαίδευσης απέναντι στη χρησιμότητα των διδακτικών σεναρίων με τη χρήση των ΤΠΕ. [Primary Teachers' attitudes towards the usefulness of educational scenaria with the use of ICTs]", in Mikropoulos, T. et al. (eds.), *Proceedings of the 10th Pan-Hellenic and International Conference "ICT in Education"*, HAICTE. [194]

Xue, S. et al. (2021), "Building an online community of practice through WeChat for teacher professional learning", *Professional Development in Education*, Vol. 47/4, pp. 613-637, https://doi.org/10.1080/19415257.2019.1647273. [215]

Yang, W., S. Kewalramani and J. Senthil (eds.) (n.d.), *Achieving the in STEAM framework with ECEC teachers in Australia*, Routledge. [82]

Yelland, N. (2018), "A pedagogy of multiliteracies: Young children and multimodal learning with tablets", *British Journal of Educational Technology*, Vol. 49/5, pp. 847-858, https://doi.org/10.1111/BJET.12635. [15]

Yelland, N. (2017), "Teaching and learning with tablets: A case study of twenty-first century skills and new learning", in Kucirkova, N. and G. Falloon (eds.), *Apps, Technology and Younger Learners: International Evidence for Teaching*, Routledge. [32]

Yelland, N. and J. Masters (2007), "Rethinking scaffolding in the information age", *Computers and Education*, Vol. 48/3, pp. 362-382, https://doi.org/10.1016/J.COMPEDU.2005.01.010. [119]

Yurtseven Avci, Z., L. O'Dwyer and J. Lawson (2020), "Designing effective professional development for technology integration in schools", *Journal of Computer Assisted Learning*, Vol. 36/2, pp. 160-177, https://doi.org/10.1111/JCAL.12394. [226]

Zetta, V., S. Papakonstantinou and G. Apostolidis (2009), "Αξιολογώντας την επιμόρφωσης Β΄ επιπέδου για την αξιοποίηση των ΤΠΕ στην Εκπαιδευτική Διαδικασία στους φιλολόγους Σερρών, Δράμας και Καβάλας. [Evaluating the B' Level training and implementation of ICTs in the educational practice by Literacy teachers]", *Proceedings of the 1st Educational Conference on the Integration and Use of ICT in Educational Process*. [193]

Zimmer, W. and S. Matthews (2022), "A virtual coaching model of professional development to increase teachers' digital learning competencies", *Teaching and Teacher Education*, Vol. 109, https://doi.org/10.1016/J.TATE.2021.103544. [224]

Annex A. Common key terms related to digital technologies

- **Computational thinking (CT):** is the understanding of concepts such as representation, algorithms and modularisation. In the context of ECEC, computational thinking can mean children's understanding of representation and simple sequences (algorithms). CT is a cognitive ability, whilst coding is the mastery of a particular programming language for problem solving and creative expression, for which computational thinking is necessary.
- **Coding:** is a means of expression for children, rather than solely a problem-solving activity. The ultimate learning goal may not necessarily be simple technical proficiency, but rather a fluency to convey and interpret ideas through the making of projects. In the context of computational thinking skills, coding is seen primarily as a problem-solving activity that engages children with abstraction and logic while developing computational thinking (Bers, 2017[144]; 2018[124]; 2019[125]).
- **Programming**: is the ability of children to master computational ways of thinking and ways of expressing themselves in any programming language that is developmentally appropriate for young children. Coding and programming invite new ways of thinking and problem solving and enable the creation of computational interactive artefacts.

The most common and widely used haptic technology includes:

- **The Internet of Things (IoT):** The concept is a network of physical devices that are digitally enabled and allow the collection and manipulation of data (Kopetz, 2011[233]).
- **The Internet of Toys (IoToys):** is derived from the Internet of Things (IoT) and this refers to "a future in which digital and physical entities can be linked, by means of appropriate information and communication technologies, to enable a whole new class of applications and services" (Ling et al., 2021[58]; 2022[234]; Miorandi et al., 2012, p. 1497[235]). Although visionary when the term was first coined in 1999, the IoT is already operational with smartphone apps that remotely control home-based objects from distant locations, as well as wearable technology measuring owners' sleep patterns, heart rate, and exercise regimes (Sung, 2015[236]). Internet-connected toys build on these technological successes. Such toys include: Hello Barbie and Smart Toy Bear, which use voice and/or image recognition, connecting to the cloud to analyse, process, and respond to children's conversations and images. Other examples are: app-enabled toys such as drones, toy cars and robots (Star Wars, BB-8 Droid); toys-to-life, which connect action figures to video games (e.g. Skylanders, Amiibo); puzzle and building games (e.g Osmo, Lego Fusion); and children's technology wearables such as smartwatches and fitness trackers.
- **Artificial intelligence (AI):** is a rapidly developing technology which is gaining popularity in daily life. AI is used to perform tasks that normally require human intelligence, such as thinking and acting (e.g. spam filters on emails, Google search, manufacturing robots, or smart assistants such as Siri or Alexa). AI is being used in toys for young children (e.g. robots). In the last 20 years, there has been the rise of the interface paradigm: Robotic User Interface (RUI). RUIs are advanced AI toys where, in contrast to other technological toys (remote-controlled toys), 'the interface [is not] to a robot which then executes a certain action but the robot being the interface to another system' (Bartneck and Okada, 2001, p. 131[237]). Such toys either look like tools or animals or are anthropomorphic, enabling the child user the opportunity to programme the interface to create interactive projects (Kewalramani, Kidman and Palaiologou, 2021, p. 652[44]).

For example, robots that have face/voice recognition functions can also talk back and have conversations with children or can be coded to perform certain tasks. Additionally, the physical appearance of the robots can modify the perception that humans have of their behaviours (Kewalramani et al., 2021, p. 46[116]).

- **Augmented reality (AR) and virtual reality (VR) technologies** AR apps enable virtual objects and artefacts to be layered over the physical environment, whilst VR fully immerses the user in a virtual world. In this document, we explore some of the research undertaken by researchers in the DigiLitEY Cost Action and examine the ways in which AR and VR might be used in settings. Marsh et al. (2018[92]) studied children's use of AR and VR apps and outlined five key principles which should underpin the use of AR and VR in the classroom. These are discussed later in this review.
- **Robotics (emphasis on educational ones):** is a multidisciplinary field of study in the areas of human-robot interaction; affective and cognitive sciences for interactive robots; design philosophies and software architectures for robots; learning, adaptation and evolution of robotic intelligence. Robotics has become a potential solution to various fast-rising demands in society, for example, in the context of ECEC, to provide solutions in various areas to improve the quality of education and life of children with disabilities and improve companionship and social interactions. Robotics studies involve robots communicating and interacting in a human-like social manner. This means that robots must perceive natural social cues from human users, such as facial expressions and gaze, and respond with "anthropomorphic" social cues.

Annex B. Methodology of the review

Our review of the literature followed the Preferred Reporting Items for Systematic and Meta-Analyses (PRISMA) approach for conducting transparent reports that are based on literature reviews (Page et al., 2021[24]).

The search explored:

1. **Reference databases**: Social Sciences Citation Index (SSCI); SCOPUS, ISI web of science, EBSCOhost, Education resources information centre (ERIC), ACM Digital Library, IEEE Xplore, and Springer.
2. **Websites**: Ministries of Education (ECEC in OECD countries) for policy documents in relation to the topic.
3. **Handbooks** of ECEC training programmes in different countries.
4. **Organisations and Associations** for peer-reviewed conference proceedings such as:
    - World Organisation for Early Childhood Education (OMEP)
    - International Society for Technology in Education (ISTE)
    - European Early Childhood Education Research Association (EECERA)
    - British Early Childhood Research Association (BECERA)
    - Early Childhood Australia (ECA)
    - European Education Research Association (EERA)
    - British Education Research Association (BERA SIG Early childhood)
    - UNESCO
    - OECD
    - Digital Child Association
    - World Bank
    - UN
    - ICITL (https://icitl.org/).

Inclusion criteria of studies were the following:

- **Type of publications**: published in peer review journals/books, after 2000, handbooks, systematic reviews and metanalyses, professional reports by government organisations or Ministries of Education or Universities, peer-reviewed proceedings from different associations.
- **Content of publication**: all study designs, any language, including specifically digital technology professional development (or as part of Science, Technology, Engineering, Mathematics (STEM)/Science, Technology, Engineering, Arts, Mathematics (STEAM) etc).

Exclusion criteria of studies were the following

- **Content of publication:** very small, private initiatives of small scale (e.g. one class, small case studies of 1-5 teachers).