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A systematic literature review of empirical research on technology education in early childhood education

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Abstract
Technology education in early childhood education (ECE) has only recently been established internationally as a curriculum content area. The interdisciplinary character of technology education and its status as a field under development occasion a need to distinguish and define technology in the merging of disciplines. This literature review presents an overview of technology education in ECE in recent empirical studies. The literature review was carried out systematically, resulting in 23 studies that were scrutinised to present an overall picture regarding study design, findings and how technology is characterised. The analysis of the nature of technology in the reviewed studies builds on DiGironimo's (Int J Sci Education, 33(10):1337–1352. https://doi.org/10.1080/09500693.2010.495400, 2011) conceptual framework, representing five distinct but merging dimensions of an ever-changing human technological creation process. In the synthesised findings, four subthemes derived from the studies' overall themes were identified: two focusing on preschool teachers and pre-service teachers, and two focusing on technology activities with children. The aligned outcomes are discussed concerning the conceptual dimensions of technology, along with possibilities, challenges and implications for the current field of research on technology education in ECE.

Keywords Technology education · Preschool · Early childhood education · Literature review

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Introduction

Today, children grow up in a society with rapid technological developments and encounter a wide range of technologies in their everyday lives. To enable children to develop an understanding of the nature of technology, technology education as part of schooling from the early years is considered essential. This is not least because it is expected to have implications for children's future possibilities to actively participate in the democratic societal discourse related to technology (Chesloff, 2013; Fox-Turnbull, 2018; van Keulen, 2018). Even though technology education has been considered important for early childhood education (ECE) since the 1800s, when Froebel introduced and Montessori developed the subject, it has mostly been framed as 'making' things in terms of craft, visual arts or play (de Vries, 2018; Fleer, 2000; Siraj-Blatchford & Mac Leod-Brudenell, 1999; Turja et al., 2009; Yelland, 1999). Moreover, technology education in ECE is intertwined with other subjects, such as art, science, engineering, mathematics and digital technologies (Lippard et al., 2017). These aspects imply that technology as a curriculum content area is less established in preschool practices (de Vries, 2006), and motivates this synthesis of existing research to explore how technology education is characterised in ECE.

In this literature review, we follow a previous comprehensive synthesis of the field published in this journal by Jones et al. (2013), which offered a useful basis for understanding technology education. Even though their focus was not on technology education in ECE specifically, many of the aspects they highlighted provided valuable input for this literature review. Jones et al. (2013) pointed out that there is a lack of consensus on the main characteristics that constitute technology, and technology education is also fragile in many curricula internationally, which potentially offer both advantages and disadvantages:

> As a strength, technology education can build and reflect on the development of other education disciplines in terms of learning from the development of curricula and pedagogy, and research approaches. The weakness lies in its fragility in terms of status as a subject, establishment of professional bodies, the support required for teacher preparation and professional learning, and the socio-political environment of schooling. In addition, despite its developing history, technology education is in many countries and school jurisdictions still a fuzzy concept. (Jones et al., 2013, p. 192)

The quote accounts for an insufficient common understanding of the nature of technology education generally, which is exemplified by how technology is defined, how it is treated in policy documents and teacher training programs and whether technology is viewed as a goal or as a means of teaching. This insufficient understanding of technology education also applies to ECE (eg. Johansson, 2021; Öqvist & Högström, 2018; Sundqvist, 2021).

Aim and research questions

The objective of the literature review is to present an overview of technology education in ECE in recent empirical studies. The aim is to analyse what the synthesised findings can tell us about the emerging field of research and how technology education is characterised based on DiGironimo's (2011) five conceptual dimensions. We asked the following research questions of the literature:

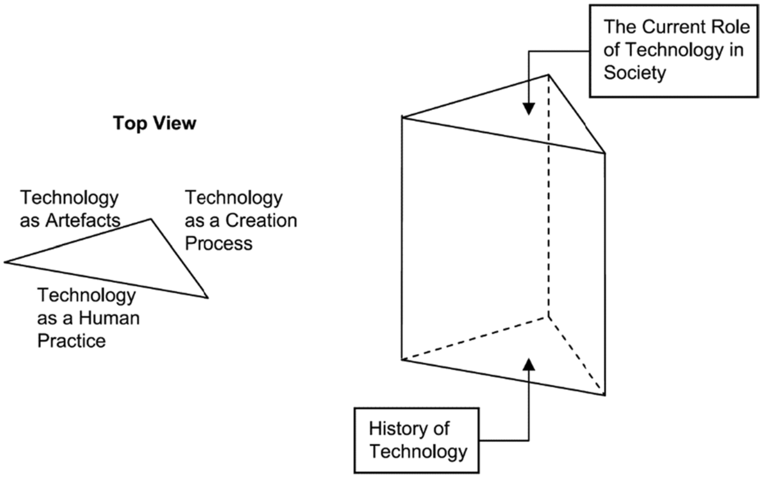

Fig. 1 Dimensions of the nature of technology. DiGironimo's theoretical model, where the nature of technology is presented using five dimensions. (DiGironimo, 2011, p. 1341, the figure is published here with permission by Nicole DiGironimos, personal communication 04–10-21)

1. What aligned outcomes of technology education in ECE can be drawn from the findings?
2. What conceptual dimensions of the nature of technology (DiGironimo, 2011) emerge in technology education studies in ECE?

The conceptual framework of the nature of technology by DiGironimo

To classify the nature of technological knowledge that emerged in the studies included in this literature review, we drew on DiGironimo's (2011) conceptual framework, since it was developed for interpreting how technology education is conceptualised in empirical studies. Furthermore, the framework, which draws on historical, philosophical and educational perspectives of technology, strongly emphasises the historical dimension of the nature of technology. This implies a focus on how and why technological artefacts were developed and connects the situational aspects and the dependence between human intentions, the functionalities of technological artefacts and solution-oriented processes, all of which are central to conceptualising technology as a human enterprise. The framework was also initially tested empirically in an analysis of data generated in a study in middle school (DiGironimo, 2011) and has subsequently been used mostly for exploring technology education in school practices (e.g. Fernandes et al., 2018; Liou, 2015; Svenningsson, 2020).

In this review, we seek to extend the framework as a lens on studies in ECE contexts.

To characterise the nature of technology, DiGironimo's (2011) framework identifies five dimensions of knowledge. These dimensions are modelled in the shape of a prism with a triangular base (Fig. 1).

As illustrated in Fig. 1, the three sides of the prism represent technology (1) as artefacts, both as products of technological innovation and as technological processes; (2) as a creation process, which describes technology as what is needed to engage in a technological process or system of processes, both physically, such as technological objects, and mentally, such as specific content knowledge; and (3) as human practice, which embraces social, cultural and ethical aspects of human involvement in the technological creation process. These three sides are all in contact, and one side (dimension) cannot exist without the other two; they comprise what DiGironimo (2011) defines as 'the shape and structure of technology' (p. 1341). The base and top of the prism, respectively, represent the fourth and fifth dimensions. The base represents (4) the history of technology concerning aspects such as when and why technical artefacts were first created to encompass the accumulated knowledge of humans, while the upper end of the prism encompasses (5) the constant changes of technology in society today and concerns the different ways in which individuals can experience and understand technology over time. The standing prism (Fig. 1) 'is meant to represent that the enterprise of technology, like any human enterprise, grows out of its past' (DiGironimo, 2011, p. 1341). Thus, the prism reflects five distinct but simultaneously merging dimensions representing the ever-changing and progressing human technological creation process (DiGironimo, 2011).

Method

Performing systematic reviews of empirical studies consists of an approach with a clear strategy for synthesising previous research. However, it should not be seen as a mechanical method to extract certain values from research but rather as viewing previous research in light of various findings by highlighting and discussing the different aims, perspectives and, in this review, the categorisations of technology education that underpin them (cf. Gough, 2007; Gough et al., 2012).

Search procedure

Based on the research questions, this paper presents the results of a systematic research review according to the sequence suggested by Gough (2007, p. 218–219). With the review questions informing the protocols, we searched for technology education in the ECE literature in three major databases: (i) Scopus, (ii) a joint search in the Online Education Database and Education Resources Information Center (ERIC) databases (ProQuest) and (iii) Education Research Complete (EBSCO). Scopus was selected for its coverage of a wide array of peer-reviewed, multidisciplinary studies across scientific, medical, social sciences, arts and humanities and technical studies. The EBSCO databases were selected for their education specialisation. The inclusion criteria for database searches were peer-reviewed empirical scientific studies written in English. The time span was delimited to studies published from 2013 to 2020, building on the synthesis by Jones et al. (2013) and allowing DiGironimo's analytical framework (2011) to have some impact. A further inclusion criterion was a focus on technology education within the ECE age group, specifically the first eight years of a child's life. The selected studies thus include data concerning both preschool and early school years since the year for starting school differs between countries. We tried out other subject exclusion terms (such as mathematics, science, IT, etc.), but these criteria excluded some studies that focused on technology education. Therefore, we conducted a broad search of the databases and thereafter manually excluded studies. This led us to use the following search terms in all databases:

'technology education' OR 'technical education'
AND

'preschool' OR 'kindergarten' OR 'early childhood'

After searching the databases and omitting duplicates, this sequence generated 125 records.

Review procedure

For the first review process, the three researchers read the abstracts individually and screened the studies of the 125 records utilising the inclusion criteria (see Fig. 1). In this sequence, we used the web application Rayyan[1] to process the article inclusion, whereby the researchers first individually assessed whether the articles should be included in the online spreadsheet provided by the application. This first screening sequence resulted in 12 included, 68 excluded and 45 conflicting (meaning that all three researchers disagreed on either inclusion or exclusion). This was followed by a rereading of the 45 records by the research team and a further in-depth round of manual screening for their relevance to the review, resulting in a further seven records being included. The outcome of the process was thus 19 included and 106 excluded. The most prominent exclusion reason was that the studies focused on irrelevant topics, for example, digital technologies, mathematics, natural science, biology and so on (79), wrong population, such as older students (23), and reflection papers not based on empirical material (4).

To include relevant studies that were not part of our corpus but were frequently referred to in the reviewed studies, the final step in our selection was to conduct a chain referral sampling method (Biernacki & Waldorf, 1981). The same inclusion criteria as before were used in this final step. This led to the further inclusion of four records, completing the final corpus of 23 records that formed the basis of review (see Table 1).

Analytical process

For the continuing analysis of the 23 articles, protocols were completed to structure the individual readings of the studies. We documented the bibliographic details of each of the studies according to citations, year, author(s), title, journal, keywords and where the studies were conducted. Furthermore, we documented the aims, theoretical frameworks and methods to synthesise the findings of the studies and to analyse and evaluate how technology education was characterised in terms of DiGironimo's (2011) five conceptual dimensions. Throughout the process, the researchers discussed and refined all protocols to improve the review. Initially, broad categories of what we interpreted to be the focus and the main findings of the studies were developed and subsequently refined to the final overarching themes and subthemes, which were agreed upon by all researchers (see Table 2). The themes and subthemes are, however, partly overlapping, and some studies have interests that could be placed in more than one theme (see, e.g. Milne et al., 2013; Thorshag & Holmqvist, 2019).

The next step was to identify the emerging conceptual dimensions of the nature of technology in each study, drawing on deductive qualitative content analysis (Cohen et al., 2018).

[1] Rayyan is a web-based application that enables researchers to individually conduct reviews on a spreadsheet and subsequently to work collaboratively by including other researchers' suggestions for article inclusion on an online spreadsheet. https://rayyan.qcri.org/welcome.

Deductive content analysis is often used in cases where the researcher wishes to retest existing data in a new context. It is generally based on earlier work such as theories, models, mind maps and literature reviews (Elo & Kyngäs, 2008) as in this case where the understanding of technology education in the corpus was scrutinised by means of the framework by DiGironimo (2011). The content analysis was thus based on DiGironimo's (2011) understanding of the dimensions of technology as (1) artefacts, (2) a creation process and (3) human practice, which together are conceptualised as *the shape and structure of technology* (the sides of the prism; see Fig. 1). In turn, these three dimensions can be related to the *enterprise of technology* consisting of the bottom of the prism as (4) the history of technology and the top of the prism as (5) the current role of technology in society. To analytically scrutinise whether these dimensions emerged in the studies in our corpus, we first identified the object of the studies. Then, we used the same set of guiding questions, discussed and refined jointly by the researchers, for each of the studies (see Appendix 1) to investigate how the object of the studies related to the first three dimensions. Following DiGironimo's (2011, p. 1344 ff.) analysis, we related both the *history of technology* and the *current role of technology in society* to the first three dimensions. Finally, we used time aspects to question whether the object of the studies applied to dimensions four and five. Even though DiGironimo (2011) underlined that the dimensions should be regarded as connected, this analytical phase made it possible to identify which essential dimensions emerged related to the object of study (see Table 3). Lastly, the identified emerging dimensions were documented in the table below, in which the categorisations as well as the objects of the studies are included.

Results

The territorial scope of the corpus resulted in 16 studies from Europe, five from Australia/New Zealand and two from the United States (US). Distribution over the years was fairly even. Theoretically, an interdisciplinary field emerged in the studies with underpinnings based in disciplines like psychology, sociology, philosophy and learning sciences. Two common perspectives were situative approaches and various kinds of design theories or models, which many of the studies combined. The most common method was interviewing, which was also used in combination with ethnographic work, and some studies involved a participatory research design, such as a design-based approach or learning study. For an overview of theoretical and methodological underpinnings, see Appendix 2.

In the following section, we present the results of our review, starting with the aligned outcomes that could be drawn from the findings of the corpus, with examples from the studies. Thereafter, we will account for the conceptual dimensions of the nature of technology (DiGironimo, 2011) that emerged in technology education, followed by examples from the studies.

The aligned outcomes from the findings of the reviewed studies

The focus of the empirical data in the reviewed studies was either on preschool teachers' and preservice teachers' understandings of technology education or on technology activities in preschool settings. The aligned findings of the studies are presented in two broad overall themes consisting of four overlapping subthemes. Two of the subthemes emerged from the studies focusing on preschool teachers' and preservice teachers' understandings, while the other two subthemes arose from the studies focusing on activities with children in preschool settings (see Table 2).

Preschool teachers' and preservice teachers' content-specific technology knowledge

Within this theme, the most prominent mutual finding in all studies was the significance of supporting teachers in developing content-specific technology knowledge. Important associations between pre-service teachers' attitudes towards technology and their potential to include real-life examples were also shown to enhance technology knowledge (e.g. Avsec & Sajder, 2018). Three of the studies examined preschool teachers' understanding of the purpose of technology education in preschool and what activities they included in technology education (Öqvist & Högström, 2018; Sundqvist & Nilsson, 2018; Sundqvist et al., 2015). An interview study by Öqvist and Högström (2018) showed that preschool teachers had difficulties in defining technology and therefore regularly chose ready-made teaching materials. Moreover, in unplanned technology activities initiated by the children, the teachers often responded with an avoidance approach due to their limited knowledge. In a questionnaire study by Sundqvist and Nilsson (2018), artefacts were shown to have a central place in technology education. The study concluded that technology education as construction activities consists mainly of providing children with materials and the opportunity to use them creatively. In another study conducted on the same dataset, Sundqvist and colleagues (2015) presented preschool teachers' perceptions of the purpose of technology education in preschool, using five categories: (1) develop children's interest in technology, (2) make children aware of everyday technology, (3) give the children an understanding of how technology works, (4) support children's technology learning through solving problems and (5) prepare the children for future learning. The study concluded that preschool teachers seem to have a rather broad understanding of technology education; however, whether their teaching mirrors their rhetoric is a question for further research.

Preschool teachers' and pre-service teachers' development of professional pedagogical knowledge related to technology education

The key finding of this theme, which was expressed in several studies, was that enabling a supportive and collaborative learning context for preschool and pre-service teachers is crucial to develop competence for teaching the subject and thereby being able to organise play-based, hands-on and collaborative activities, which are crucial for young children's learning (Sjoer & Meirink, 2015; Hultén & Björkholm, 2016; Arikan et al., 2017; Simoncini & Lasen, 2018). More specific suggestions in the studies within this theme are to increase teachers' subject-specific language (Hultén & Björkholm, 2016) and awareness of gender aspects (Hedlin & Gunnarsson, 2014).

An ethnographic study of preschool teachers' perceptions of and experiences with technology by Arikan et al. (2017) showed that experience-based, collaborative learning activities can develop the teachers' organisation of technology education. Similar findings were presented in a learning study by Hultén and Björkholm (2017) and a case study by Sjoer and Meirink (2015), in which teachers' team meetings and collaborative framing were considered valuable for teachers' professional development.

A study by Hedlin and Gunnarsson (2014), based on a thorough review of the perspective of technology as masculine-coded, focused on gender aspects. The review indicated that female preschool teacher students often have little experience with the subject and often carry negative experiences from their technology education. Hedlin and Gunnarsson (2014) argued that 'masculine-coding is associated with a gender division of subjects that occurs at school' (p. 1957). A conclusion is that by highlighting aspects of gender, gendered patterns of behaviour among girls and boys can be avoided.

Technology activities in preschool settings: emphasising the relation between teaching and learning

The studies included in this broad theme concentrate on learning activities with children in preschool settings. An overall finding of the studies is the suggested framing of technology education as a way to also learn to collaborate, whereas no common view emerged on how structured or free the learning activities should be. Thus, to accomplish collaborative technology education, some studies point to children's free choice as significant for success (Looijenga et al., 2015; Thorshag & Holmqvist, 2019), while others argue that learning is more effective when it is well structured and organised (Fox-Turnbull, 2016; Hallström et al., 2015; Johansson, 2021; Looijenga et al., 2016; Milne, 2013). One example of the former is an ethnographic study by Looijenga and colleagues (2015), in which children's freedom of choice was shown to be important for the children's collaboration and learning process. In addition, in a study by Thorshag and Holmqvist (2019), the findings suggested that the possibilities to make decisions were particularly important for children's learning. A different conclusion was stated in Fox-Turnbull's (2016) ethnographic study of different age groups in which the six-year-old children were relevant for this review. The findings showed that at the outset of a clear task, the children's collaborative work was most significant, since the children had to talk and listen to others' ideas, make compromises and sometimes accept ideas other than their own.

Another study that suggests that more structured teaching is important for supporting children in developing a shared language about technology is an intervention study by Looijenga et al. (2016), which contrasts two cases. In the first case, where the technology activity was distinctly initiated and supported by the teacher, the findings showed that the activity evolved as a team process with a shared language. In the second case, the teacher presented the environment but not the tasks, which led to a process that, in some respects, became undefined. Kilbrink et al. (2014) reported challenges with children's free choice in a learning study in which the findings suggested that children had difficulties distinguishing between a product and a process when subject-specific content received less attention. Sundqvist's (2020) ethnographically inspired study showed that teachers promoted children's learning of technology content by relating both to technological objects and creative processes. Additionally, studies by Johansson (2021) and Bartholomew and colleagues (2019) underline the significance of teachers' introduction and support in children's collaborative problem-solving activities. One ethnographic study within this theme (Hallström et al., 2015) points to the importance of teachers' interventions when it comes to gender aspects to avoid gendered patterns of behaviour among girls and boys.

Technology activities in preschool settings: emphasising children's experiences

The key finding in the last broad theme, which focuses on educational activities in preschool settings, is the importance of highlighting the process rather than the product and to include the children's previous experience. For example, in a case study by Yliverronen

(2014) aimed at exploring how pre-schoolers make connections between the different stages of a design process, the findings showed how the teachers supported the children in developing technology knowledge during the ongoing project. It was concluded that, with moderate assistance, the children understood the importance of the process. A similar study conducted by Yliverronen et al. (2018) focused on children's collaboration and interaction and the role the children assumed in groups during a design session. The findings showed how the children managed collaboration through a combination of oral and non-oral communication, and authentic technology activities were argued as important since they 'provide a natural real-life situation to cooperate' (p. 19).

In two case studies (Mawson, 2013; Milne & Edwards, 2013), the findings specifically highlighted the importance of acknowledging children's previous experience of technology. In Mawson's study (2013), the findings suggest that children come to preschool with well-developed technological competence to investigate and carry out technological tasks. However, 'this knowledge and competence is not recognised and taken advantage of by the majority of primary early years programme developers and teachers' (11, p. 451). Milne and Edwards (2013) found that children often have uncritical explanations of how things are made, with a focus on the materials rather than the process, and they often use their imaginations to explain when needed, which makes technology education crucial for their developed understanding. In the study, the importance of drawing on children's broad range of experiences and ideas from a more critical angle is highlighted.

Conceptual dimensions of technology emerging in the studies

In all the reviewed studies, technology education could be characterised in terms of at least one of DiGironimo's (2011) conceptual dimensions. Table 3 presents what dimensions, at times interwoven since they are all connected, emerge in the studies. As previously described in our scrutiny of the studies to analytically identify the dimensions, we specifically draw on whether the dimensions emerged in the formulations of aims, research questions and in the discussion of the results (see Table 3).

The most prominent dimensions that emerged in the reviewed studies are *technology as a human practice* (23), followed closely by *technology in relation to the current role in society* (22), *technology as an artefact* (16) and *technology as a creation process* (14). Only one study also clearly embraced *technology in relation to history* (1).

Technology as an artefact

The results of our analysis suggest that the dimension of *technology as an artefact* emerged in 16 of the studies, in terms of the products of technological innovation; that is, the artefacts and the materials that the children interact with, such as everyday objects used in preschool activities and their daily lives (e.g. Mawson, 2013; Hallström et al., 2015; Loijenga et al., 2015; Fox-Turnbull, 2016; Hultén & Björkholm, 2016; Arikan et al., 2017; Avsec & Sajdera, 2018; Öqvist & Högström, 2018Johansson, 2021). Sometimes, the teacher's goal of emphasising artefacts is to make the children aware of the technology surrounding them (e.g. Sundqvist & Nilsson, 2018) or to discuss the children's understanding of the artefacts (Milne & Edwards, 2013). Artefacts are also approached in terms of how to handle them by practical rule knowledge and invoke new knowledge by letting the children investigate them (Sundqvist, 2020). Some studies centre specifically on the artefact that the children are to create (e.g. a bridge) and compare it with similar artefacts (Kilbrink et al., 2014) or focus on objects used in construction play (Yliverronen, 2014); for example, how materials can be combined to make houses or vehicles (Thorshag & Holmqvist, 2019). One study addressed children's different approaches to open-ended design problem activities, depending on the offered task and material (Bartholomew et al., 2019).

Technology as a creation process

According to our analysis, the studies (14) that include the dimension of *technology as a creation process* assume that technology education should involve hands-on activities (Kilbrink et al., 2014) and sometimes emphasise the importance of involving a creative design process (Avsec & Sajdera, 2018; Fox-Turnbull, 2016; Milne, 2013; Yliverronen, 2014), whereby the children utilise their natural curiosity and problem-solving abilities when constructing things (Hallström et al., 2015; Sundqvist, 2020; Sundqvist & Nilsson, 2018; Yliverronen, 2014) and sometimes uncritical knowledge (Milne & Edwards, 2013). Studies that draw on *technology as a creation process* argue that children should be given possibilities to interact with technical objects and focus on the process, which means that 'the learner has to recognise a task as a means, instead of as an end' (Looijenga et al., 2015, p. 42). One study addresses how children's different problem-solving approaches depend on the task and differ between the various stages in the design process, which points to the significance of how teachers organise technology activities (Bartholomew et al., 2019). Some studies that include the creation process dimension relate it to the importance of teacher–child interaction (e.g. Fox-Turnbull, 2016; Kilbrink et al., 2014) and conclude that teachers' ways of communicating about technology enable children to learn different aspects through the process (Johansson, 2021). An overall view is that it is important to include creation processes as part of technology education to support children's understanding by making use of the technology they are surrounded by in their daily lives. This is discussed by Yliverronen and colleagues (2018). The emerging view of technology as characterised in terms of both *a creation process* and *a human practice* is thus common in the reviewed studies (see Table 3).

Technology as a human practice

The dimension of *technology as a human practice* was found in all studies of the corpus by embracing the elaboration of human involvement in the technological creation process and ethical, cultural, political and environmental values. This is examined in the reviewed studies by discussing the different purposes of everyday objects and real-life problems (Kilbrink et al., 2014; Milne, 2013) and involving human enterprises, such as engineering (Avsec & Sajdera, 2018). The dimension of *technology as a human practice* also implies that children's attention should be drawn to technology within the surrounding context, involving children's experiences outside the preschool, talking about how an artefact is valued in relation to humans and society (Johansson, 2021) and supporting children to think about its usability (Hultén & Björkholm, 2016; Looijenga et al., 2015; Mawson, 2013; Sundqvist & Nilsson, 2018; Yliverronen, 2014). Furthermore, this dimension accounts for gender-related aspects, such as how girls and boys encounter technology activities differently (Hallström et al., 2015).

History of technology

According to our analysis, by concentrating on whether the dimensions emerged while formulating the aims and discussing the results, only one of the studies (Johansson, 2021) in our corpus explicitly involved the dimension of the *history of technology.* In a study, Johansson (2021) introduced the concept of companion meanings as value judgements about what knowledge is and what kinds of knowledge are worth acquiring. The author then used this concept to highlight the significance of teachers´ role and how they organise technology education to discuss when and why technical artefacts were created, thereby enabling children to reflect on the relation between technology, humans, society and history. Within a preschool context, this implies, for example, teaching about what humans have invented throughout history and what that means for us.

Historical aspects are mentioned in other studies in our corpus (Hallström et al., 2015; Hedlin & Gunnarsson, 2014; Sundqvist & Nilsson, 2018), but since the reasoning in the studies is not explicitly related to the object of the studies or discussed in relation to the results, the historical dimension is not considered as emerging in the studies. In Fox-Turnbull's (2016) study, activities involving older children can be interpreted as concerning historical aspects, but as mentioned previously, the part of this study involving older age groups is not included in this review.

The current role of technology in society

In all but one of the corpus's studies (Thorshag & Holmqvist, 2019), the dimension of *the current role of technology in society* is identified as emerging. This dimension relates to the constant changes in our societies and concerns aspects such as how individuals experience and understand technology differently. Sundqvist and Nilsson (2018) describe the different levels that need to be presented in preschool: 'Children should use the artefacts, they should create their own artefacts, and they should understand the artefacts in terms of both how they work and how they are best used and for what purpose' (p. 43). Several studies point out that since children often uncritically draw on a broad range of experience to explain how things are made, it is important to involve the children's prior knowledge in technology education to build on their understandings or sometimes to modify incorrect preconceptions (e.g. Mawson, 2013; Milne, 2013; Milne & Edwards, 2013; Sundqvist et al., 2015). This dimension also involves how teachers can direct the children's focus to companion meanings (value judgements) around technology to open up more critical reflections on the relationship between technology and society (Johansson, 2021). Further aspects of this dimension involve explaining and discussing the different purposes of everyday objects (Öqvist & Högström, 2018) and how they can be used to solve daily life problems (Yliverronen et al., 2018). Another aspect involves the current gender issues of society; for example, Hallström and colleagues (2015) emphasise that children need to be introduced to technology as early as possible to deliberately address gendered patterns of behaviour among girls and boys (Hallström et al., 2015). Gender aspects are also raised from the preschool teachers' perspective; Hedlin and Gunnarsson (2014) showed that many female teachers had negative experiences with the school's technology education, which influenced their current work.

Discussion

This review set out to present an overview of empirical research published from 2013 onwards in ECE. The corpus included both preschool teachers' and pre-service teachers' understandings of their work with technology with children and studies on how technology has been used thus far during early childhood activities. The aim was to analyse what the synthesised findings can tell us about the field of ECE technology education in recent empirical studies and what dimensions of the nature of technology emerged in line with DiGironimo's (2011) conceptual framework. In general, it is clear that technology education in ECE is an emerging field – all the studies in our corpus are based on the assumption that it is of great importance to increase technology education for young children and, to a large extent, the studies also include suggestions for developing and improving the educational practices of technology education in preschool and early years education.

The nature of technology in the research field of ECE

Drawing on DiGironimo's (2011) conceptual framework and the intention of developing an internally consistent definition of technology and determining its utility for teaching middle school students, we applied the framework to ECE contexts when analysing how understandings of the nature of technology emerged from the reasoning in the reviewed studies. Instead of testing the conceptual framework on questionnaire data, as DiGironimo did (2011), we explored what conceptual dimensions of technology emerged in ECE studies. As reported in the Results section, most of the reviewed studies are analytically shown to involve several of the dimensions of technology, as shown in Table 3. Between two and five dimensions were identified as emerging in the reviewed studies in our corpus – most common were four emerging dimensions and the least common were all five dimensions. The two dimensions that stand out were *Technology as a human practice* (23 studies) and *Technology in relation to the current role in society* (22 studies), which were identified as emerging in almost all studies. The fact that the dimension of *technology as human practice* appears in all studies included within the corpus indicates that the studies have a clear focus on understanding technology education as a practice in the specific pedagogical context of ECE settings. It is also interesting to note that the arguments in most studies are so closely related to technology in contemporary society. This could be understood as the compliance of practitioners' adaptions to political requirements to provide a qualified technology education that educates future citizens. While the dimensions of technology as artefacts, as creation processes, as human practice and as technology in today's society are well represented within the body of studies reviewed here, the only dimension that is underrepresented is the history of technology. In general, the studies in our corpus focusing on preschool teachers' or pre-service teachers' understandings of technology education had fewer prominent dimensions than the studies focusing on technology activities in preschool settings. What this might indicate will be further elaborated on below.

In the following, we will discuss the aligned outcomes that can be drawn from the findings and the characterisation of technology education in the reviewed studies using DiGironimo's (2011) two-fold divisions: (i) *the shape and structure of technology*, which is represented by the three sides in the prism (see Fig. 1); and (ii) *the enterprise of technology,* which, as all human endeavour builds on history and develops towards the future, illustrates the present role of technology in society as an ongoing process. We will relate the

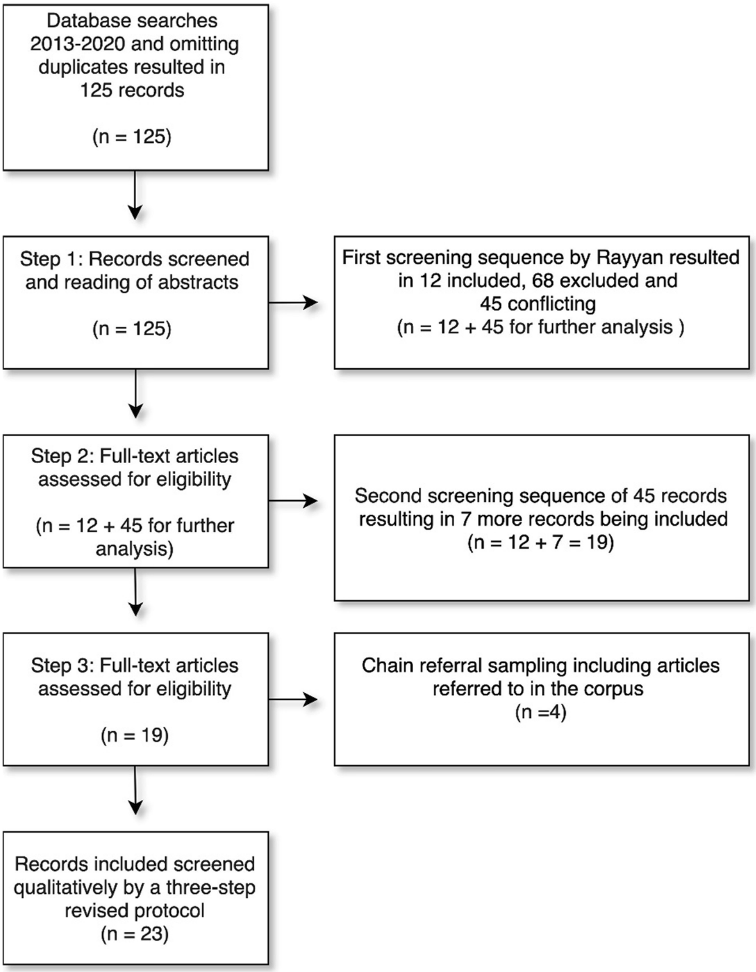

Fig. 2 Flowchart of the selection of articles in the review process

aligned outcomes of the overall themes and subthemes to discuss what this means in terms of possibilities, challenges and implications for the current field of research on technology education (Fig. 2).

The shape and structure of technology emphasised in the empirical studies

DiGironimo (2011) argues that each of the three dimensions, *technology as artefacts*, *technology as a creation process* and *technology as a human practice*, which characterise the shape and structure of technology, indicates 'that no side can exist without the other' (p. 1341). The reviewed studies focusing on technology activities situated in preschools showed a strong interest in the aspects encompassed by these three dimensions. Thus, technology education appears to be largely characterised by the shape and structure of technology in the reviewed studies. The shape and structure of technology are not as prominent in

Table 1 The corpus of 23 studies that formed the basis of the review

1. Arikan, A., Ferniem D. E., & Kantor, R. (2017). Supporting the Professional Development of Early Childhood Teachers in Head Start: A Case of Acquiring Technology Proficiency. *Elementary Education Online, 16*(4), 1829–1849. https://doi.org/10.17051/ilkonline.2017.342996
2. Avsec, S., & Sajdera, J. (2019). Factors influencing pre-service preschool teachers' engineering thinking: Model development and test. *International Journal of Technology and Design Education, 29*(5), 1105–1132. https://doi.org/10.1007/s10798-018-9486-8
3. Bartholomew, S., Moon, C., Ruesch, E., & Strimel, G. (2019). Kindergarten Students' Approaches to Resolving Open-Ended Design Tasks. *Journal of Technology Education, 30*(2), 90–115. https://doi.org/10.21061/jte.v30i2.a.6
4. Fox-Turnbull, W. (2016). The nature of primary students' conversation in technology education. *International Journal of Technology and Design Education, 26*(1), 21–41. https://doi.org/10.1007/s10798-015-9303-6
5. Hallström, J., Elvstrand, H., & Hellberg, K. (2015). Gender and technology in free play in Swedish early childhood education. *International Journal of Technology and Design Education, 25*(2), 137–149. https://doi.org/10.1007/s10798-014-9274-z
6. Hedlin, M., & Gunnarsson, G. (2014). Preschool student teachers, technology, and gender: positive expectations despite mixed experiences from their own school days. *Early Child Development and Care, 184*(12), 1–12. https://doi.org/10.1080/03004430.2014.896352
7. Hultén, M., & Björkholm, E. (2016). Epistemic habits: primary school teachers' development of pedagogical content knowledge (PCK) in a design-based research project. *International Journal of Technology and Design Education, 26*(3), 335–351. https://doi.org/10.1007/s10798-015-9320-5
8. Johansson, A. (2021). Examining how technology is presented and understood in technology education: a pilot study in a preschool class. *International Journal of Technology and Design Education 31*, 885–900. https://doi-org.ezproxy.ub.gu.se/10.1007/s10798-020-09584-z
9. Kilbrink, N., Bjurulf, V., Blomberg, I., Heidkamp, A., & Hollsten, A. (2014). Learning specific content in technology education: learning study as a collaborative method in Swedish preschool class using hands-on material. *International Journal of Technology and Design Education, 24*(3), 241–259. https://doi.org/10.1007/s10798-013-9258-4
10. *Looijenga, A-M., Klapwijk, R., & de Vries, M. (2015). The effect of iteration on the design performance of primary school children. *International Journal of Technology and Design Education, 25(*1), 1–23. https://doi.org/10.1007/s10798-014-9271-2
11. Looijenga, A-M., Klapwijk, R., & de Vries, M. (2016). Groundwork: Preparing an Effective Basis for Communication and Shared Learning in Design and Technology Education. *Design and Technology Education, 21*(3), 41–50
12. Mawson, W. (2013). Emergent technological literacy: what do children bring to school? *International Journal of Technology and Design Education, 23*(2), 443–453. https://doi.org/10.1007/s10798-011-9188-y
13. Milne, L. (2013). Nurturing the designerly thinking and design capabilities of five-year-olds: technology in the new entrant classroom. *International Journal of Technology and Design Education, 23*(2), 349–360. https://doi.org/10.1007/s10798-011-9182-4
14. Milne, L., & Edwards, R. (2013). Young children's views of the technology process: An exploratory study. *International Journal of Technology and Design Education, 23*(1), 11–21. https://doi.org/10.1007/s10798-011-9169-1
15. Öqvist, A., & Högström, P. (2018). Don't Ask Me Why: Preschool Teachers' Knowledge in Technology as a Determinant of Leadership Behavior. *Journal of Technology Education, 29*(2), 4–19. https://doi.org/10.21061/jte.v29i2.a.1
16. Simoncini, K., & Lasen, M. (2018). Ideas about STEM Among Australian Early Childhood Professionals: How Important Is STEM in Early Childhood Education? *International Journal of Early Childhood, 50*(3), 353–369. https://doi.org/10.1007/s13158-018-0229-5
17. Sjoer, E., & Meirink, J. (2015). Understanding the complexity of teacher interaction in a teacher professional learning community. *European Journal of Teacher Education, 39*(1), 1–16. https://doi.org/10.1080/02619768.2014.994058

Table 1 (continued)

18. Sundqvist, P. (2020). Technological knowledge in Early Childhood Education: provision by staff of learning opportunities. *International Journal of Technology and Design Education, 30*(2), 225–242. https://doi.org/10.1007/s10798-019-09500-0
19. Sundqvist, P., & Nilsson, T. (2018). Technology education in preschool: providing opportunities for children to use artifacts and to create. *International Journal of Technology and Design Education, 28*(1), 29–51. https://doi.org/10.1007/s10798-016-9375-y
20. *Sundqvist, P., Nilsson, T., & Gustafsson, P. (2015). The purpose of technology education in pre-school: Swedish preschool staff's descriptions. In M. Chatoney (Ed.), *Plurality and Complementary of Approaches in Design and Technology Education, PATT29 conference proceedings*, pp. 390–396. Apr 2015, Marseille, France. 2015, 978–2-85,399–994-6
21. *Thorshag, K. & Holmqvist, M. (2019). Pre-school children's expressed technological volition during construction play. *International Journal of Technology and Design Education*, 1–2. https://doi.org/10.1007/s10798-018-9481-0
22. *Yliverronen, V. (2014). From Story to Product: Pre-schoolers' Designing and Making Processes in a Holistic Craft Context. *Design and Technology Education: An International Journal, 19*(2), 8–16. https://ojs.lboro.ac.uk/DATE/article/view/1954
23. Yliverronen, V., Marjanen, P., & Seitamaa-Hakkarainen, P. (2018). Peer Collaboration of Six-Year Olds When Undertaking a Design Task. *Design and Technology Education: An International Journal, 23*(2), 1–23

Studies marked with * were included through a chain referral sampling method

Note that this study was published online July 2022

the reviewed studies interested in preschool teachers' or pre-service teachers' understandings of technology education. In these studies, the dimension of *technology as a human practice* emerged in all nine studies identified within this overall theme. The dimension of *technology as artefacts* emerged in about half of the studies (5), and the dimension of *technology as a creation process* emerged in only two of the nine studies within this overall theme. This illustrates that previous studies have, to a large extent, been selective when exploring teachers' understandings of the shape and structure of technology as part of technology education and may well indicate a knowledge gap in research.

The empirical studies that were identified as characterising technology education in terms of *technology as artefacts* take an interest in objects and tools, that is, the materiality of artefacts. The findings of the reviewed studies showed that children in early childhood education, in general, have many opportunities to learn about the everyday artefacts that surround them and how to use them, something often taught by practical rule knowledge. This can be related to the most basic technological knowledge, such as discovering artefacts in everyday life and learning to handle artefacts by using them (cf. Sundqvist & Nilsson, 2018). As established in the introduction, technology education has by long tradition often been framed with the goal of producing a technological artefact or system (Siraj-Blatchford & Mac Leod-Brudenell, 1999). Therefore, it is not surprising that many of the reviewed studies show that teachers tend to maintain well-known ways of working and centre on activities in which children create an artefact (cf. Turja et al., 2009). However, the activities often focused on the end product—that is, the artefacts produced. This focus on products that the children are to produce also relates to a continuing discussion among scholars whereby teachers' design of 'technology education as a linear process' is seen as a problem, as it 'lies in direct contrast to how children actually work' (Fleer, 2000, p. 44). Furthermore, if children are unfamiliar with the properties of a material, it is harder for

Table 2 Aligned outcomes on technology education in ECE of the reviewed studies

Overall themes	Focusing on preschool teachers and pre-service teachers' understandings of technology education		Focusing on technology activities in preschool settings	
Subthemes	Emphasising preschool teachers' and pre-service teachers' content-specific technology knowledge	Emphasising preschool teachers' and pre-service teachers' development of professional pedagogical knowledge related to technology education	Emphasising the relationship between teaching and learning	Emphasising children's experi-ences
Studies	2, 15, 19, 20	1, 6, 7, 16, 17	3, 4, 5, 8, 9, 10, 11, 13, 18, 21	12, 14, 22, 23
Sum of studies	4	5	10	4

Table 3 Technology education, in terms of DiGironimo's (2011) five dimensions emerging from the reviewed studies

Dimensions of technology education	(1) Technology as an artefact	(2) Technology as a creation process	(3) Technology as a human activity	(4) Technology in relation to the history of the subject	(5) Technology in relation to its current role in society
Studies	1, 2, 3, 4, 5, 7, 8, 9, 10, 12, 14, 15, 18, 19, 21, 22	2, 3, 4, 5, 8, 9, 10, 13, 14, 18, 19, 21, 22, 23	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23	8	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 23
Sum of studies	16	14	23	1	22

Note that in some of the studies, several dimensions emerged in one same study them to take part in the technology process and transform the material at hand into a final product (Milne & Edwards, 2013).

Studies characterising technology education by the dimension of *technology as creation processes* often invoke the doings or methods of technology through collaborative learning activities (DiGironimo, 2011; Siraj-Blatchford & Mac Leod-Brudenell, 1999; Yelland, 1999) and focus on design processes and how to create artefacts. The creation process is repeatedly stressed as significant for children's development of technological knowledge (e.g. Avsec & Sajdera, 2018; Fox-Turnbull, 2016; Kilbrink et al., 2014; Looijenga et al., 2015; Yliverronen et al., 2018). When technology education is characterised by this dimension, it is understood as introducing play-based and hands-on activities where children are provided with materials to use creatively, drawing on the children's previous experiences or interests and allowing the children to invoke their free will. Thus, some of the studies in the corpus characterise technology education as creation processes in terms of liberated and less organised activities. Other studies have highlighted the importance of introducing structured and organised activities (Fox-Turnbull, 2016; Milne, 2013). However, supporting children in focusing on a holistic process obscured the critical aspects of the technology content, which was the intended goal of the activity (Kilbrink et al., 2014; Sundqvist, 2020). DiGironimo (2011, p. 1348) highlighted this dilemma by arguing that it is difficult to 'discuss the process of making or creating new technologies without also mentioning the actual technologies themselves (i.e. the artefacts)'. This points to the overall educational difficulty of organising and valuing ongoing activities, entailing an even greater challenge for the children in understanding the goal in terms of a process and not an end product (cf. Kilbrink et al., 2014).

The empirical studies categorised as involving the dimension of *technology as a human practice* are interested in understanding how different social groups (teacher students, teachers and children) perceive technology and how technology activities can be organised to employ social interaction and collaboration. An overarching view of this dimension can be understood as providing opportunities for children to talk and ask questions about technology and to develop an understanding of, and a critical and responsible approach to, technology in everyday life. Several of the studies highlight collaboration, communication, reflection and negotiation as well as the significance of using subject-specific language for children to develop technology knowledge (e.g. Fox-Turnbull, 2016; Hultén & Björkholm, 2016; Johansson, 2021; Mawson, 2013; Yliverronen et al., 2018). Studies also point to the vague perception of technology education among preschool teachers and teacher students, which is sometimes related to their own negative previous experiences of technology in school (e.g. Hallström et al., 2015; Hedlin & Gunnarsson, 2014). In addition, the result showed that when faced with children's genuine interest in technological objects or processes, teachers tend to either be dismissive or compensate by using ready-made activities, which they do not fully understand (Öqvist & Högström, 2018). Many of the studies in the corpus (e.g. Looijenga et al., 2016; Milne, 2013; Sundqvist, 2020; Thorshag & Holmqvist, 2019; Yliverronen, 2014) point out that teacher–child social interaction and negotiation are key for fruitful technology education. In relation to this, a challenge for the field of research and practice is teachers' vague perception of subject specific knowledge, and how it relates to their ability to introduce and make explicit subject-specific concepts and also influences their leadership behaviour towards active teaching in both planned and spontaneous activities.

As will be elaborated in the next paragraph, only one of the scrutinised studies explicitly included historical aspects in the object of the study, which metaphorically implies that research on technology education in ECE can be understood as unstable without a solid base in the long-term evolution of technology.

The enterprise of technology is not fully taken into consideration

The *historical dimension of technology* can be understood as teachers providing children with knowledge about technology as accumulated by humans throughout history. In our corpus, none of the studies formulated an interest in the time aspect as its prominent object of inquiry in terms of scrutinising children's understandings of how technology is developed over time (history) or that contemporary technology is a result of previous innovations. As the dimension of the *history of technology* emerged explicitly in only one study (Johansson, 2021), the historical dimension was considered to be represented in the corpus only shallowly. However, as previously presented, our analysis is based on how the historical dimension emerged in the formulation of the aims and research questions and in the discussion of the studies' results, although this does not mean that historical aspects are not discussed at all in the other studies. For example, one of the studies examined in this review (Sundqvist & Nilsson, 2018) addressed the aspect of technology as the accumulated knowledge of humans by drawing attention to preschool teachers' views of using artefacts as a means to start communicating about how they work and about the history of technological artefacts. However, according to the results of the reviewed studies, specific technology content in hands-on activities is seldom verbalised by teachers (e.g. Hultén & Björkholm, 2016; Öqvist & Högström, 2018; Sundqvist & Nilsson, 2018). This implies that even if the artefacts themselves and their use are accompanied by a certain, though often unacknowledged, historical dimension, this is not made explicit. Hence, knowledge of the historical dimension of technology in general is not explicitly discussed and is therefore not part of the analytical agenda of the studies. This foregrounds the importance of teachers having a shared content-specific language to enhance the distinguishing of technology as subject content, enabling communication and collaboration in technology activities, sharing previous experiences and knowledge and providing an opening for supporting children in their emerging technology knowledge.

The dimension of the current role of *technology in contemporary society* could be understood as both an overarching dimension that is intertwined with the others and also as a less stable dimension, since the role of technology in society is complex and ever changing over time (DiGironimo, 2011). This dimension also incorporates the necessity of involving the preschool teachers', pre-service teachers' and children's previous knowledge as a base when developing knowledge on technology (e.g. Mawson, 2013; Milne, 2013; Milne & Edwards, 2013; Sundqvist et al., 2015; Avsec & Sajder, 2018). Johansson (2021) emphasised the significance of directing children's focus to companion meanings; these are related to artefacts and design processes to open up a more critical reflection on the relation between technology, humans, society and nature, all of which fit into DiGironimo's (2011) five dimensions. However, the absence of a critical theory became evident when scrutinising the reviewed studies (cf. Petrina, 1998). Only one of the studies (Hedlin & Gunnarsson, 2014) within the corpus of our review makes knowledge claims that are rooted in some kind of critical perspective, which in the study relates to how gender issues become intertwined with the teacher students' views on their technology education. In this study, gender is elaborated on as constructed in activities and routinely masculine-coded, whereas preschool teachers are often female with relatively little experience of the subject or experience that is negative (Hedlin & Gunnarsson, 2014). To acknowledge that 'technology is not immune to gender, race, or class distinctions' (DiGironimo, 2011, p. 1339), we discern the need for further research about this dimension of technology.

Limitations, implications and further research

Since technology education in ECE is a growing area of research, our review of this emerging field of study is perhaps most useful for highlighting what is *not* considered in the existing evidence base. Given the perception of technology education as a multidisciplinary field, different definitions could certainly be used as a basis for analysis; therefore, we make no claim that the overview presented here is exhaustive or the single valid way to describe the field. One limitation of this review is that we have not explored the territorial differences of the studies in terms of how technology education diverges from the national curricula, which was one of Jones et al. (2013) main objectives. This could certainly imply that we overlooked aspects concerning the themes of the reviewed studies that were particularly related to the representations of technology education emphasised in local policies. Furthermore, DiGironimo's (2011) framework in itself can be understood as a limitation for understanding technology education since it is a way of classifying and thereby delimiting the understanding of technology. However, we suggest that categorising the reviewed studies based on DiGironimo's (2011) conceptual framework has proved its relevance by pointing to specific dimensions of the nature of technology that are notable due to their minor coverage in the extant literature. The objectives of the reviewed studies were recurrently on artefacts and materials rather than on the processes and the history and role of technology in today's society. This implies the necessity of researching technology education from a holistic perspective, where real-life problems, collaboration and interactions of the children are further studied. The shared implications of this literature review indicate a need for enhanced technological subject knowledge for early childhood educators to be confident in involving technology education activities, enabling them to recognise the importance of including the different dimensions of technology and making this knowledge explicit within ECE practices.

Furthermore, preschool teachers' technological subject knowledge and their perceived subject knowledge must be acknowledged as highly significant for the content, organisation and quality of technology education in ECE. Gender aspects are also imperative, as a majority of preschool teachers in ECE are women, and research shows the importance of technology education, especially for girls (cf. Axell & Boström, 2019; Hallström et al., 2015; Hedlin & Gunnarsson, 2014; Turja et al., 2009; Virtanen et al., 2015), since this will have an impact on their future perception, attitudes and how they participate in a technological society.

Conclusions

This review has shed light on the dimensions that mainly characterise how technology education in ECE is outlined in research and which dimensions are infrequently involved. From the results of this review, it is evident that the prism drawn to illustrate the five dimensions of technology education (DiGironimo, 2011) metaphorically has a weak base, since it rests on the dimension of *the history of technology*, which is a dimension that is seldom addressed in studies on technology education in ECE. This implicit common ground of technology education could contribute to the difficulty of distinguishing the subject from adjacent fields and specifically involving educational technology activities in early years education. Consequently, when the historical dimension is not included in the understanding of technology, it becomes difficult to understand modern technological advances, and the understanding of technology as a fundamental part of all civilisations and of humanity itself is diminished. In agreement with Jones and colleagues (2013), this literature review shows that by articulating the discipline and utilising historical and philosophical perspectives, researchers can contribute to an understanding of current technology education in schooling and in our case in ECE. The research field of technology education in ECE specifically emphasises the need to reach agreement regarding the definition of technology education, and this literature review suggests that DiGironimo's framework can be employed in this process.

In a global society, developing technology knowledge and an understanding of the nature of technology has implications for the individual's emerging critical thinking, decision-making and active participation in sustainable societies. To conceptualise technology as a human enterprise, the historical dimension is essential. Based on the results of this review, we specifically suggest further research involving the historical and future aspects of technology education in preschools. In ECE, this would imply making explicit how the use and design of objects and tools have changed alongside the differing needs of humans and how humans have gradually changed how we manage the physical world. For children growing up in a highly technological society, it is certain that learning and developing technological knowledge are crucial, and this education can favourably start in preschool.

Appendices

Appendix 1

Guiding questions for the analysis

The analysis draws on DiGironimo's (2011) understanding of the sides of the prism involving the dimensions of technology as (1) artefacts, (2) a creation process and (3) human practice, which together are conceptualised as *the shape and structure of technology*. In turn, all these dimensions can be related to the *enterprise of technology* consisting of the bottom of the prism as (4) the history of technology and the top of the prism as (5) the current role of technology in society. To analytically scrutinise whether these dimensions emerged in the studies in our corpus, we first identified the object of the studies. Then, we asked the questions in the table below to each of the studies to investigate how the object of the studies related to the first three dimensions. Following DiGironimo's (2011, p. 1344 ff.) analysis, we related both the history of technology and the current role of technology in society to the first three dimensions, which are seen in the questions asked. Finally, we involved time aspects to further question whether the object of the studies related to dimensions four and five.

Technology as	Guide for analyses
1. An artefact	The products: Is the interest of the study to explore the participants' understandings of what technology is and their use in the pedagogical setting (the products of technological innovation, the educational technology tools used in the classrooms: tools, objects or processes [internet, machines, cars, factories, etc.])? Are the researchers' interests/arguments/discussion related to either dimension, (4) history or (5) the role in society?
2. A creation process	The processes: Is it the interest of the study to explore the participants' understandings of *how* technological artefacts are designed, created or developed (e.g. design processes)? Is it the interest of the study to explore the participants' engagement in the design processes of tools and objects (skills, knowledge and tools needed for creation/production of technology)? Are the researchers' interests/arguments/discussion related to either dimension, (4) history or (5) the role in society?
3. Human practice	The practices: Is it the interest of the study to explore who is engaged in the creation process and what role people play within the practice (e.g. the study relates to the participants' personal values or beliefs when creating or using artefacts within a specific context, setting, educational system, etc.)? Is it the interest of the study to explore/discuss the dimensions of technology as a human enterprise related to political, cultural, societal, ethical, environmental, economic or personal values and beliefs? Are the researchers' interests/arguments/discussion related to either dimension, (4) history or (5) the role in society?
4. The history of technology	Time aspects: Is the interest of the study positioned in relation to aspects of the history of technology (e.g. when and why artefacts are created, developed and used)?
5. The current role of technology in society	Time aspects: Is the interest of the study positioned in relation to the current role of technology in society (the role of technology in relation to the participants' everyday lives, education systems, disciplines in science, etc.)?

Appendix 2

Theoretical frameworks and methods used in the reviewed studies.

Theoretical basis	Theoretical basis not explicitly elaborated	Grounded theory	Situative/pragmatist-socio-historic basis	Traces from cognitive theories	Variation theory	Sociology of childhood	Gender theory	Theories of design, models, typology or frameworks
Studies	13, 19, 20, 21, 22	1, 17	1, 4, 7, 8, 12, 14, 23	2, 11, 15	9, 21	5	6	2, 3, 7, 10, 11, 16, 18
Sum of studies	5	2	8	3	2	1	1	7

Note that the studies sometimes combine frameworks.

Methods used for generating data in the reviewed studies.

Methods	Interview (structured, semi-structured, unstructured, focus group, stimuli recall)	Ethnographic approach (field-notes, audio recording)	Design-based learning study	Survey (multiple choice, written answer)	Video observation
Studies	1, 4, 5, 12, 13, 14, 15, 17, 21, 22	1, 4, 5, 8, 9, 10, 11, 12, 13, 18, 22	2, 3, 7, 9, 22	2, 6, 16, 19, 20	5, 9, 17, 21, 23
Sum of studies	11	11	6	6	5

Note that the studies sometimes combine methods

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Authors' contributions SE has been active in the planning of the article and is the person responsible for the background of the review and was main responsible when conducting the systematic selection. All authors contributed to the study conception and design. All authors contributed to literature research, data analysis process, analysis, and text drafts, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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