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Code-Related Activities and Their Association With Early Literacy Skills: A Scoping Review and Meta-Analysis

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ABSTRACT

Literacy skills are acquired during childhood through 'code-related activities', which are interactions and practices that directly engage children with written words. This study presents a scoping review and meta-analysis of 18 peer-reviewed articles that explore the relationship between these code-related activities and early literacy skills. The analysis revealed a diverse range of samples, with participants from 12 countries speaking 10 different languages. However, many studies exhibited significant gaps in demographic information, omitting crucial details such as socioeconomic status, the number of languages spoken by children, the presence of disabilities, and which parent participated in the study. All studies utilised questionnaires to gather data; however, the content of these instruments varied significantly and often focused on limited reading resources. Despite these limitations, a small but significant positive correlation was found between code-related activities and early literacy skills. The analysis also highlighted high heterogeneity and potential bias, which may be attributed to inconsistencies in measurement across the studies. In conclusion, while there is evidence suggesting a link between code-related activities and early literacy skills, more thorough and comprehensive research is needed to better understand the influence of the home literacy environment. Future studies should aim to address the existing demographic and methodological gaps to provide a clearer picture of this relationship across diverse populations.

1 | Introduction

Literacy is an individual's ability to use the acquired skills of reading and writing to participate in society, achieve their goals and develop their knowledge and potential (OECD 2013). It is considered a human right and a life skill critical for the prosperity of people and communities (UNA—UK, 2017). Children start school with some necessary skills and knowledge that help them to learn to read, which develop from infancy due to various factors (Hutton et al. 2021; Sénéchal, Whissel, and Bildfell 2017). These are called early literacy skills and are defined as 'children's procedural literacy knowledge, including knowledge of letter names and sounds, as well as initial reading and spelling attempts' (Sénéchal, Whissel, and Bildfell 2017, 385).

The acquisition of these skills may have long-lasting effects (Sénéchal, Whissel, and Bildfell 2017). To ensure children's success at school, it is important to understand and promote the development of reading and writing skills before they enter formal education (Snow, Burns, and Griffin 1998). The Home Literacy Environment (HLE) is an environmental factor that has been linked to the development of early literacy skills (Hutton et al. 2021; Puglisi et al. 2017; Zuilkowski et al. 2019). HLE is an umbrella term, which comprises different aspects of

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the interaction between parents and their children in relation to literacy (Burgess, Hecht, and Lonigan 2002; Sénéchal and LeFevre 2014). This is the first place where children start developing their language and receive particular inputs (Akyüz and Doğan 2017; Altun, Tantekin Erden, and Snow 2018; Stockall and Dennis 2013; Westerveld et al. 2015). As such, it is important to study the HLE to understand children's literacy learning trajectories and help those who struggle with literacy attainment. Sénéchal and LeFevre therefore propose the evidence-based *home literacy model* that formalises certain activities such as parents teaching their children to read and/or write as 'code-related-activities' (2014). These activities have been linked with the development of early literacy skills, but more evidence is needed to support this claim (Sénéchal, Whissel, and Bildfell 2017).

In the literature, different perspectives describe specific types of early literacy skills. Whitehurst and Lonigan (1998) mentioned language (oral language, such as semantic, syntactic and background knowledge), narrative (understand narratives and produce one's own), conventions of print (knowledge of the standard format of print), knowledge of graphemes (letter-name knowledge), phonological awareness (to identify rhymes, manipulate syllables and phonemes), syntactic awareness (to correct grammatical mistakes), phoneme–grapheme correspondence (letter-sound knowledge and pseudoword decoding), emergent writing (phonemic spelling), phonological memory (a type of short-term memory for phonologically coded information), rapid naming (to quickly name letters, numbers or colours) and print motivation (to be interested in print shared reading). Here, early literacy skills are independent but can influence each other.

In contrast, the comprehensive emergent literacy model (Rohde 2015) posits that early literacy skills overlap and are influenced by the individual's community, culture and demographics. According to the model, early literacy skills are language (adds vocabulary to the previous definition), print awareness (alphabet knowledge and concepts about print) and phonological awareness (to identify and manipulate sounds). While this model distinguishes only four literacy skills, some definitions merge separate concepts used by Whitehurst and Lonigan (1998). For example, print awareness includes conventions about print and grapheme knowledge.

It should be noted that including oral and written language measures in the same construct could lead to confounds when assessing possible links between HLE and child outcomes (Sénéchal et al. 2001). Therefore, Sénéchal, Whissel, and Bildfell (2017) distinguish between oral language (children's knowledge of spoken language, usually assessed by vocabulary), phonological awareness, early literacy skills and reading skills (acknowledging, however, that they are interrelated). In this model, early literacy skills are threefold: letter knowledge (knowledge of the names and sounds of letters), early reading (initial reading, word recognition and decoding) and writing (initial writing attempts, printing, invented spelling and spelling) (Sénéchal, Whissel, and Bildfell 2017). In the following, this study will adopt this position when referring to early literacy skills.

Despite findings that suggest HLE is linked to early literacy skills (Hutton et al. 2021; Puglisi et al. 2017; Zuilkowski et al. 2019), its measurement and outcomes vary across studies (Baroody and Diamond 2012), in part because of its different conceptualizations. For Payne, Whitehurst, and Angell (1994), it includes the frequency of activities in the home that are related to literacy, such as parent–child reading, parent's attitudes towards literacy and number of books in the home. Leseman and de Jong (1998) measured opportunity, instruction, cooperation and socioemotional quality of the HLE. Buchs et al. (2011) considered family engagement in learning, family involvement in school learning and exposure to printed materials. In a meta-analysis performed by Dong et al. (2020), four dimensions of HLE were considered: parental literacy beliefs, parental education, parental involvement in children's activities and home literacy resources.

In the home literacy model, there are two types of literacy activities that take place between parents and their children within the HLE. On one hand, formal or code-related activities are mainly focused on the features of print. Simply put, parents teach children about letters in ways that can be playful, informative or didactic. According to the model, these promote the acquisition of early literacy skills and can be helpful with learning the mechanics of reading. On the other hand, informal or meaning-related activities (i.e., shared reading) focus on the meaning represented by print and promote the development of oral language (Sénéchal 2006; Sénéchal and LeFevre 2002; Sénéchal, Whissel, and Bildfell 2017).

Considering these conceptualizations, it seems that the number of literacy resources and the actions of parents play crucial roles in the HLE. In fact, meaning-related activities are the most studied aspect of the HLE, especially its association with children's vocabulary (Bus, Van IJzendoorn, and Pellegrini 1995; Sénéchal, Whissel, and Bildfell 2017). To this end, book exposure is sometimes used as a proxy measure for shared reading (Sénéchal, Whissel, and Bildfell 2017). Because there is less research that focuses on code-related activities, the rest of this section discusses the interaction between different variables and the HLE in general. This issue will be addressed in the study purpose section.

Although having books at home does not necessarily mean families will read them, a meta-analysis conducted by de Bondt, Willenberg, and Bus (2020) suggested that book giveaway programmes promote shared reading within families. This resulted in children scoring higher on literacy-related behaviours and skills. However, few studies distinguish between the specific roles mothers and fathers play in the HLE (Liu and Hoa Chung 2022). Research in this field tends to include only mothers, probably because of persisting traditional gender roles (Liss et al. 2013). Another explanation could be the link between maternal education and children's academic outcomes and language development (Reardon 2011), but there is also evidence that fathers (e.g., Liu and Hoa Chung 2022; Xiao et al. 2020) and even siblings (e.g., Segal et al. 2018) have a unique impact on children's cognition and literacy development.

In addition, there are other variables that influence the HLE and children's early literacy skills. According to Suggate et al. (2018), socioeconomic status (SES) might influence both cognitive and literacy development by mediating the educational opportunities children can access, such as exposure to print and shared reading opportunities. There is evidence that parents' involvement at home can vary by SES (e.g., Buckingham, Beaman, and Wheldall 2014) and that children benefit more from parents who are literate (UNA—UK 2017). Furthermore, HLE has been studied mostly in English-speaking countries (Davis 2016), and the difficulty of learning to read may vary depending on the type of orthographic script (Sénéchal, Whissel, and Bildfell 2017). Early literacy skills can also be influenced by factors such as the number of languages spoken by the individual (Kennedy and McLoughlin 2022) and disabilities that impact language development (Graham et al. 2020).

HLE can be measured using instruments such as questionnaires, interviews, and observations. A critical analysis of 52 HLE studies from the USA showed that most authors used questionnaires or surveys (59.61%), and 36.5% of them combined direct observations and interviews (Davis 2016). Sénéchal, Whissel, and Bildfell (2017) conducted a literature review of 15 studies, with participants who spoke English, French, Greek, Spanish, Finnish and Chinese. They found that code-related activities were assessed through questionnaires, confirming this tendency. Although it can be argued that parental reports are suitable tools for assessing HLE because of the primary role they play (Sim et al. 2019), their reports may be affected by social desirability and recall bias (King and Bruner 2000). There is less research about the quality of parent–child interactions during code-related activities (Sénéchal, Whissel, and Bildfell 2017).

To avoid the aforementioned biases, Sénéchal et al. (1996) created an indirect self-report instrument: a checklist in which parents mark the children's storybook titles they knew. However, this instrument is only suitable for measuring meaning-related activities, and its validity and reliability may depend on cultural factors. Additionally, it only assesses storybooks, ignoring other literacy resources such as familiar household items, letters, shopping lists, newspapers, games and street signs (Martini and Sénéchal 2012). It also fails to consider new literacy practices, such as the use of computers and tablets, which can also be argued for within most traditional definitions of HLE (Flewitt and Clark 2020).

2 | Study Purpose

Meaning-related activities have been studied in more detail than code-related activities (Bus, Van IJzendoorn, and Pellegrini 1995; Sénéchal, Whissel, and Bildfell 2017). The review conducted by Sénéchal, Whissel, and Bildfell (2017) suggested that code-related activities promote the acquisition of early literacy skills, but also presented evidence against it. Nonetheless, this review was not intended to be exhaustive, and a meta-analysis, combined with a scoping review, is a more systematic approach to elucidate whether this initial finding is supported by evidence, especially, because there is little research related on this topic to date. A meta-analysis will also allow calculating the impact of code-related activities on early literacy skills, based on available studies.

This not only helps fill a gap in literature, but will also be useful to design interventions to improve family's HLE and children's early literacy skills. In turn, this should have a positive impact on children's literacy skills and academic achievement (Sénéchal, Whissel, and Bildfell 2017). Therefore, the purpose of the present project was to perform a rigorous review and meta-analysis of data related to correlational studies that associate code-related activities and early literacy skills.

This paper has three aims:

- To characterise the participants included in studies that investigate the association of code-related activities and early literacy skills.
- To characterise the methods used in studies that investigate the association of code-related activities and early literacy skills.
- To determine the pooled correlation between code-related activities and early literacy skills in studies that investigate the association of code-related activities with early literacy skills.

Considering the literature, it was hypothesised that there would be a significant positive association between code-related activities and early literacy skills.

3 | Methodology

To fulfil the proposed study aims, a scoping review and a meta-analysis were conducted. The scoping review, a useful approach for mapping key concepts related to a research area (Peters et al. 2015), was guided by the first two aims of the study. The meta-analysis was performed to address the third aim. And a pooled correlation was calculated based on the correlation coefficients and sample sizes of the different studies included in the review (Borenstein et al. 2011; Deeks, Higgins, and Altman 2022).

The literature search for this study was conducted following the PRISMA guidelines (Page et al. 2021), as seen in Figure 1. EBSCO, Eric (ProQuest), SCOPUS and Web of Science databases were searched to find relevant peer-reviewed articles. A backwards search including studies from the review performed by Sénéchal, Whissel, and Bildfell (2017) was also conducted. The following keywords were used for the forward search: 'Home Literacy Environment', 'Parent teaching', 'Literacy skills', 'Emergent literacy skills', 'Early literacy skills', 'Letter knowledge', 'Early reading', 'Writing'.

The selection of documents was performed by the first author. A total of 417 articles were obtained, after removing 361 duplicates. First, titles, abstracts and keywords of documents were screened for relevance, with 62 reports remaining. Later, selected documents were read to determine if they met the inclusion and exclusion criteria. 18 studies were obtained from this process.

Articles were selected according to the following inclusion criteria: correlational study with clear correlation coefficients, measured code-related activities, measured at least one early literacy skill, participants shared the same native language, there was a recognisable sample size, was written in English or Spanish. Experimental and quasiexperimental studies were excluded,

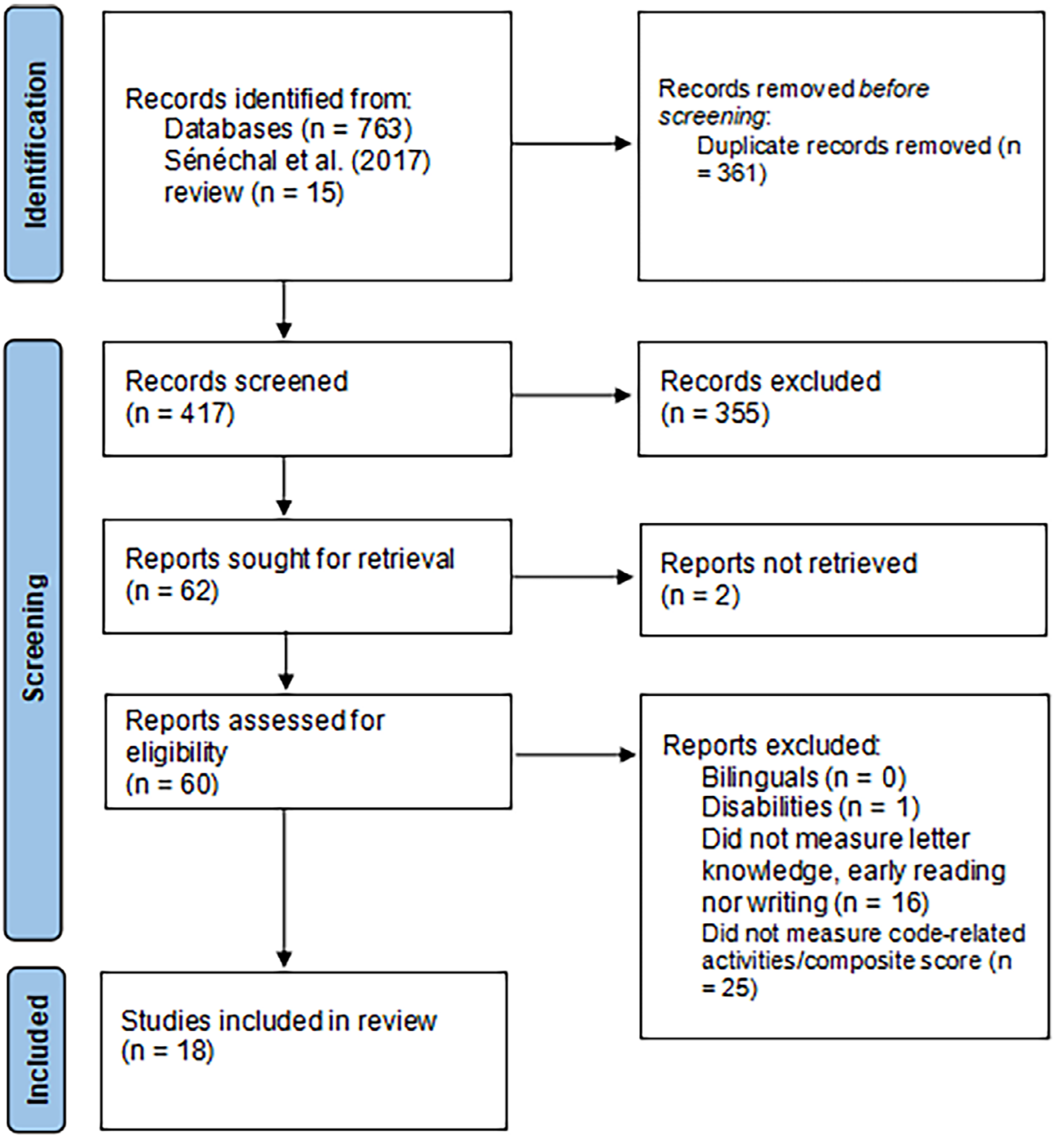

FIGURE 1 | PRISMA flow diagram. Adapted from Page et al. (2021).

as these consider interventions that can potentially modify the HLE. The present study focused on the HLEs that take place naturally.

Articles were excluded if they met at least one of the exclusion criteria: some/all participants were bilingual, some/all participants had an impairment or disability that could impact their language development, presented composite scores of HLE or early literacy skills, or measured concepts similar to HLE, such as the home learning environment. Contrary to what was expected, several articles ($n=25$) were excluded because they did not measure code-related activities or presented HLE composite scores. Another 16 studies were excluded because they did not measure letter knowledge, early reading, nor writing.

Studies that did not specify whether participants were bilingual or had an impairment or disability but met all the inclusion criteria and no other exclusion criteria were also selected, because of the small final number of studies sampled. No studies written in Spanish were found.

To perform the meta-analysis, variables were coded by the first author following the review conducted by Sénéchal, Whissel, and Bildfell (2017) and considering other variables of interest. Coding was done using Microsoft Excel. The variables were: study citation, number of participating children, children's mean age, children's sex/gender, family SES, country where the study was performed, children's monolingualism, presence of disabilities, parents involved in the study, type of study, data collection instruments, HLE measures, early literacy skills measures, literacy resources and correlations.

Because children's mean age was coded in years, sometimes it had to be calculated from mean ages in months. To code children's sex/gender (which was measured in different ways across studies) the percentage of females/girls was extracted. SES was coded Low, Middle, High or CS (composite score) as determined by authors using different methods. For example, some used family income, parent occupation, parent education, or a combination of these. Children's monolingualism was coded 'Yes' if studies specified children were monolingual, and 'NS (not specified)' if studies did not include this information. Similarly, presence of disability was coded 'No' if studies explicitly said that children with disabilities that could impact their language development were excluded, and 'NS' if this information was not mentioned. The involvement of parents in the study was coded 'Mothers' if only mothers participated, 'Mostly mothers' if more than 60% of the participating parents were mothers, 'Mothers and fathers' if both parents participated, and 'Parents' if the study did not specify further. No other family members were mentioned in the studies. The study design variable was coded 'longitudinal' or 'cross-sectional', depending on measures being taken in one or more timepoints. Early literacy skills considered were letter knowledge, early reading and writing. All HLE and early literacy skills measures were included in the data set, but only correlations between code-related activities and early literacy skills were coded, following Sénéchal, Whissel, and Bildfell (2017). Literacy resources were recorded as they were named by authors (e.g., children's books, magazines and newspapers).

Inoue et al. (2020) reported correlations for four samples from different countries who spoke different languages. Therefore, each sample was considered a separate group. For longitudinal studies, only the correlations from the first timepoints were considered (usually when children were in kindergarten), because this is when they were less exposed to formal literacy instruction. Additionally, some studies assessed different variables at other timepoints, which were not compatible with the inclusion criteria.

Data from the scoping review was analysed using descriptive statistics (Dancey and Reidy 2017). The number of participants was presented in terms of frequency and range. The total mean age of the participants was calculated using the mean ages of each study, and its range was also identified. Similarly, the range of females/girls (in percentages) was also reported. Frequencies and percentages were calculated for SES, native language, country, monolingual children, children with disabilities, participating parents, type of study, HLE instrument, early literacy measures and literacy resources.

Correlation coefficients and sample sizes from each study were analysed in the Comprehensive meta-analysis software (CMA; Borenstein et al. 2013) and the metafor package in R (Viechtbauer 2010). When studies reported more than one outcome related to the same variable (e.g., two measures of letter knowledge), their pooled correlation was calculated using regular meta-analysis procedures (assuming they were not independent). This is an acceptable alternative to dealing with multiple outcomes, although it may generate some error (Moeyaert et al. 2017). Silinskas et al. (2012) reported correlations for boys and girls separately, but since they were drawn from the same schools and shared the same nationality and native language, their pooled correlation was also calculated. In total, 30 final correlations were extracted from 18 studies (see Table A1 in Appendix A). Interestingly, eight studies (44.44%) did not present statistically significant correlations ($p > 0.05$).

To assess publication bias, an Egger's test (Egger et al. 1997) and funnel plot (Deeks, Higgins, and Altman 2022) were performed. Since studies varied in design and participants, a random effects model was used to perform the meta-analysis. Hence, correlation coefficients were transformed to Fisher's Z scores to calculate an estimated pooled correlation, and then transformed again into correlation coefficients for an easier interpretation of results (Borenstein et al. 2011; Deeks, Higgins, and Altman 2022). Calculations were made for a weighted overall early literacy skills correlation, and for letter knowledge, early reading and writing individually. Correlations equal to or higher than 0.60 were considered strong; between 0.59 and 0.30 were considered moderate, and between 0.29 and 0.10 were considered weak (Mukaka 2012). When interpreting Cochrane's test, the threshold for statistical significance was 0.10 (Greenland and O'Rourke 2008). Finally, an I^2 of less than 25% was considered low heterogeneity, up to 50% as moderate, and more than 50% was considered as high (Higgins et al. 2003).

Reporting on measurement reliability and validity was low across studies, with only 3 out of 18 studies reporting reliability measures, and 1 out of 18 reporting validity measure for HLE questionnaires. A meta-analysis of these measures has therefore not been possible.

4 | Results

The smallest sample was of $n = 35$ participants, whereas the largest sample had $n = 1436$. The mean age of the participating children was 5.74 years (considering available data). The lowest mean age was 4.17 years, while the highest mean age was 7.18. The percentage of females/girls ranged between 36.36% and 57.5%. Table 1 summarises the descriptive statistics of the sample.

It is surprising that only two (11.11%) studies reported that the participating children were monolingual (Bojczyk et al. 2015; Foy and Mann 2003). The others (88.89%) did not specify this and did not say if the children or their parents spoke a second language. Similarly, 11 (61.11%) studies reported that none of the participating children had any disabilities. The other seven (38.89%) did not specify whether this was an exclusion criterion. Regarding the participation of parents, most studies declared they included parents ($n = 10$, 55.56%), but did not specify which one. There were no studies that considered siblings or members of the children's extended families.

Regarding the methods used, nine studies (50%) were longitudinal, and the other nine were cross-sectional (50%). All studies used parent questionnaires to collect HLE data; 13 (72.22%) of them were based on other questionnaires, and five (27.77%) others did not specify if they used literature to design their instruments. Two studies (11.11%) also used title recognition checklists (Foy and Mann 2003; Hood, Conlon, and Andrews 2008), and another one (5.55%) used a dairy of daily literacy activities that parents had to complete (Zhang et al. 2020).

Some studies measured early literacy skills that were not part of the home literacy model, and therefore, out of the scope of this study (see Tables A2 and A3 in Appendix A). Regarding early literacy measures, 11 studies (61.11%) measured letter knowledge, 10 (55.56%) measured early reading and five

TABLE 1 | Summary of descriptive information of the sample.

Study citation	*N*	Age	Females/girls (%)	SES	Native language	Country	Monolingual children	Children with disabilities	Participating parents
Bojczyk et al. (2015)	112	4.73	49.10	Low	English	USA	No	Yes	Mothers
Foy and Mann (2003)	40	4.86	57.50	Mid dle	English	USA	Yes	—	Parents
Georgiou, Inoue, and Parrila (2021)	172	6.32	47.67	Mid dle	English	Canada	—	—	Parents
Hood, Conlon, and Andrews (2008)	143	5.36	45	Low	English	Australia	—	No	Parents
Inoue, Georgiou, Muroya, et al. (2018)	142	6.67	49.29	—	Japanese	Japan	—	No	Mostly mothers
Inoue, Georgiou, Parrila, et al. (2018)	214	5.6	48.13	CS	English	Canada	—	—	Parents
Inoue et al. (2020)	172	6.32	47.67	—	English	Canada	—	No	Parents
	120	6.54			Dutch	Netherlands			
	184	6.59			German				
	238	6.34			Greek	Austria			
Li and Li (2022)	223	5.21	51.13	High	Mandari n	China	—	No	Parents
Liu, Georgiou, and Manolitsis (2018)	132	5.87	53.70	CS	Mandari n	China	—	No	Mostly mothers
Participants' characteristics									
Liu and Hoa Chung (2022)	354	5.03	47.50	Lower to Middle	Cantonese	Hong Kong	—	No	Mothers and fathers
Manolitsis, Georgiou, and Tziraki (2013)	82	5.36	36.36	Middle	Greek	Greece	—	—	Mostly mothers
Neumann (2016)	101	4.17	48.51	Low and High	English	Australia	—	No	Parents
Silinskas et al. (2012)	1436	6.13	47.63	—	Finnish	Finland	—	—	Mothers and fathers
Strasser and Lissi (2009)	188	5.41	49.46	Middle- Low Middle	Spanish	Chile	—	—	Mothers
Van Tonder, Arrow, and Nicholson (2019)	35	5.14	54.30	Low to High	English	Australia	—	No	Mostly mothers

(Continues)

TABLE 1 | (Continued)

Study citation	N	Age	Females/girls (%)	SES	Native language	Country	Monolingual children	Children with disabilities	Participating parents
Wang and Liu (2021)	194	7.18	38.65	CS	Chinese	China	—	—	Parents
Westerveld et al. (2015)	92	—*	58.69	Low-mid to high	English	New Zealand	—	No	Parents
Zhang et al. (2020)	159	6.05	44.02	CS	Mandarin	China	—	No	Parents

Note: $N = 21$ groups of participants, from 18 studies.
Abbreviations: —, not specified; CS, composite score.
*The study did not specify mean, but the children had an age between 4 years and 4 years and 11 months.

(27.78%) measured writing. Furthermore, studies considered a wide variety of literacy resources in their data collection instruments. Nine studies (50%) included children's books, seven studies (38.89%) included books in general, and four studies considered storybooks (22.22%). Four studies (22.22%) also included library visits. Several literacy sources were considered only once (5.56%): flashcards or workbooks, labels (Bojczyk et al. 2015), picture books (Westerveld et al. 2015), pictures, TV or videos, educational computer programs (Foy and Mann 2003), adult books (Inoue et al. 2020), print in daily life, print in media (Li and Li 2022), alphabet resources (Neumann 2016), places where to purchase books (Strasser and Lissi 2009), word games, tablets and smartphones (Van Tonder, Arrow, and Nicholson (2019)). Finally, one study (5.56%) included literacy resources in general (Wang and Liu 2021), and another one (5.56%) did not specify the sources that were included (Inoue, Georgiou, Muroya, et al. 2018). Table A4 summarises methods information.

Figure 2 shows an asymmetrical distribution of the funnel plot of standard errors by correlation coefficients in the reviewed studies. This suggests bias, and particularly publication bias. Furthermore, an Egger's test was performed, which further supported the notion that there was significant publication bias ($t_{(19)} = 2.25$, $p < 0.05$).

Calculations found high heterogeneity between code-related activities and early literacy skills measures ($Q_{(20)} = 53.22$, $df = 1$, $p < 0.001$; $I^2 = 65.10\%$). Hence, variations between studies were not caused by chance. Furthermore, a significant but small positive correlation was found between code-related activities and early literacy skills measures ($r = 0.16$, $p < 0.001$, 95% $CI = 0.11–0.22$), as presented in Figure 3.

Table 2 shows the random effects model for the correlations of code-related activities with early literacy measures. The three literacy skills presented small, positive correlations with code-related activities. The highest correlation was between code-related activities and letter knowledge ($r = 0.22$, $p < 0.001$, 95% $CI = 0.15–0.28$), with high heterogeneity ($Q_{(14)} = 32.93$, $df = 1$, $p < 0.001$; $I^2 = 57.44\%$). Writing showed the second highest correlation ($r = 0.21$, $p < 0.05$, 95% $CI = 0.08–0.34$) and high heterogeneity ($Q_{(4)} = 10.43$, $df = 1$, $p < 0.10$; $I^2 = 61.65\%$). Early reading presented the smallest correlation ($r = 0.11$, $p < 0.001$, 95% $CI = 0.05–0.18$) and moderate heterogeneity ($Q_{(9)} = 15.63$, $df = 1$, $p < 0.10$; $I^2 = 46.51\%$). In all cases, heterogeneity was likely not caused by chance.

5 | Discussion

The purpose of this study was to perform a rigorous review and analysis of data related to correlational studies that associated code-related activities and early literacy skills. For this, a scoping review and meta-analysis were conducted. It was hypothesised that there would be a significant, positive association between code-related activities and early literacy skills. The scoping review allowed the characterisation of the participants and methodologies of the analysed studies. The pooled correlation between code-related activities and early literacy skills was obtained using meta-analysis.

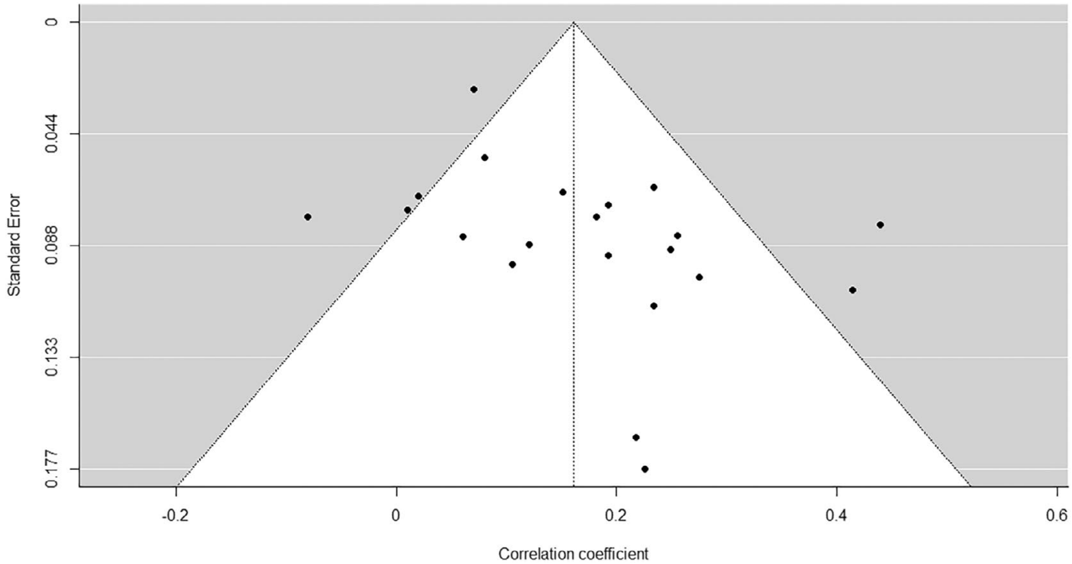

FIGURE 2 | Funnel plot of standard errors by correlation coefficient.

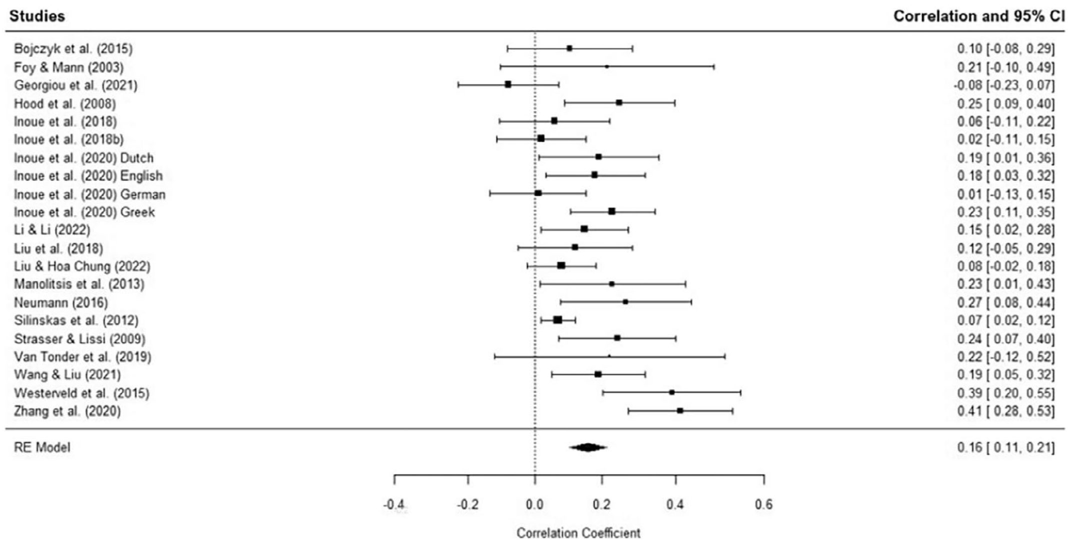

FIGURE 3 | Forest plot of *r* effect sizes and meta-analysis.

TABLE 2 | Random effects model of the correlation between code-related activities and early literacy skills.

Early literacy skill	k	n	Pooled effect (r)	95% CI (r) Lower CI	95% CI (r) Upper CI	Heterogeneity test Q (X^2)	Heterogeneity test p	Heterogeneity test I^2	Tau-squared (t^2)	Test of null (Z)
Letter knowledge	15	1960	0.24	0.17	0.31	32.93	0.00	57.44	0.010	6.53*
Early reading	10	2841	0.11	0.05	0.18	15.63	0.08	46.51	0.004	3.63*
Writing	5	604	0.21	0.08	0.34	10.43	0.03	61.65	0.014	3.15**

*$p < 0.001$.
**$p < 0.05$.

Samples in the analysed studies varied considerably in terms of size, proportion of females/girls, SES, native language spoken by participants and countries where data was collected. Only children's age was relatively uniform, likely because early literacy skills develop and are the most impactful before formal literacy education commences (Sénéchal, Whissel, and Bildfell 2017). Hence, research with older children will tend to study literacy skills. In general, findings suggest that there is important variability in the statistical power of the analysed studies due to relevant differences in sample sizes. Some studies were balanced in terms of sex/gender, but others had a higher proportion of males/boys. SES representation was more balanced than sex/gender, as there were participants from low, middle and high SES, according to the standards of each country. Strasser and Lissi (2009) even considered participants from middle-low and middle-high SES, and Westerveld et al. (2015) included participants from low-mid to high SES. However, some studies only presented composite scores for SES, and others did not specify SES at all. These discrepancies and omissions within SES measures may hinder the comparison between studies and cultures.

In line with Davis (2016), who suggested an emphasis of English-speaking countries in HLE research, nearly half of groups of participants spoke English as their native language. Nonetheless, there were also groups who spoke, Cantonese, Chinese and Japanese, showing more research in Asian languages than what was reported in the review by Sénéchal, Whissel, and Bildfell (2017). Other languages found were Greek, Dutch, Finnish, German and Spanish. Still, most data were collected in English-speaking countries: Canada, Australia, the USA and New Zealand. There also was a strong presence of non-English-speaking European countries, namely Greece, Austria, Finland and the Netherlands. Finland provided the highest proportion of participants. There was less representation from Asian (China, Japan, Hong Kong) and Latin American countries (Chile). This shows that little is known still about code-related activities in Latin American, African and Middle Eastern countries. Unfortunately, many studies omitted relevant information about their sample. In particular, additional languages spoken by children or their parents, whether participants had disabilities, or which parent participated. These omissions will be discussed in the future research section.

At first glance, the methods used in the analysed studies are more homogeneous than the participants. Half of the studies were longitudinal, and the others were cross-sectional. All studies used parent questionnaires as the main HLE data collection instruments. Most studies based their questionnaires on instruments that did not assess HLE specifically, while the others did not report if they used specific literature to design their questionnaire. Only one study used a diary of daily literacy activities for parents. A few studies combined the use of title recognition checklists with the questionnaires, but since these instruments measure meaning-related activities (Sénéchal et al. 1996), they are not useful for the purposes of this study.

We further note a general dearth of reporting and discussion of the reliability and validity of measurements in our sample. Out of the 18 studies, 10 addressed the reliability of other instruments but not HLE questionnaires, 3 addressed the reliability of the HLE questionnaires, and only 1 addressed the external validity of HLE results. It has therefore not been possible to make an inference on the reliability and validity of measurement of HLE.

Questionnaires frequently included questions about specific literacy sources, the most common one being children's books. Other resources mentioned were books in general, storybooks and library visits. Nonetheless, many literacy resources such as games and electronic devices were not considered or included just once. Thus, questionnaires tended to concentrate on more traditional literacy resources, while resources suggested by Martini and Sénéchal (2012), and Flewitt and Clark (2020) are rarely mentioned. As such, it may be possible that studies have measured only a portion of the code-related activities that really occur. Even though most questionnaires ask about literacy resources when measuring meaning-related activities, these questions could involuntarily bias parent's responses when asked about code-related activities.

It should be noted that places where books can be purchased replaced library visits in the Strasser and Lissi (2009) paper, because there were not many libraries where data could be collected. This suggests that there is heterogeneity across studied contexts. Similarly, not all early literacy skills were measured with the same frequency, although the pooled correlations obtained for each of them were similar, as discussed earlier. More than half of the studies considered letter knowledge and early reading, but only five articles reported data on writing.

It is important to mention that funnel plots are a general visualisation of bias, including publication bias, study quality, location bias and study size (Egger et al. 1997). All these types of biases could apply in this case. However, both the asymmetrical funnel plot and a statistically significant Egger's test suggest that there is publication bias. This is consistent with the fact that only articles from peer-reviewed journals were analysed, which tend to publish significant outcomes (Quintana 2015). Nonetheless, eight of the considered studies did not have statistically significant correlations between code-related activities and early literacy skills. Hence, it is still possible that other characteristics of the studies influenced these outcomes.

The meta-analysis found a small, positive, statistically significant correlation between code-related activities and early literacy skills, supporting the main hypothesis of this study. In other words, if code-related activities increased, early literacy skills increased as well and vice versa. Similar results were obtained for code-related activities and each individual early literacy skill: letter knowledge, writing and early reading. The latter presents the smallest correlation of them all. Nonetheless, it is not possible to establish a direction between code-related activities and early literacy skills, as the analysed studies were all correlational. This will be discussed further in the limitations section.

Another relevant result was the high, statistically significant heterogeneity between the studied variables. This means that there were important variations between studies. Two of the early literacy skills also presented high heterogeneity: letter knowledge and writing. Early reading presented moderate heterogeneity. It could be hypothesized that high values of heterogeneity were obtained because there were important differences between studies. Firstly, studies involved at least nine different languages (one study reported that the language was 'Chinese', but many languages are spoken in this country), and there is evidence that HLE has a different impact on literacy, depending on the language (e.g., Inoue et al. 2020). Secondly, as discussed above, most articles tended to omit relevant information, which could impact the outcomes of these studies and of this meta-analysis. Lastly, even though all studies used questionnaires to measure code-related activities, they were different instruments. It is possible that how code-related activities were defined and operationalised influenced each studies' results.

This study presents a series of limitations. As Baroody and Diamond (2012) stated, the definition of HLE in general varies between studies, as well as its outcomes. It was also discussed how the analysed studies varied in terms of participants and methodology, and how they failed to report relevant information. The number of analysed studies was rather small (Egger et al. 1997), and because of how data was presented in some studies, it is possible that there was some error in the calculations that had to be performed (Hedges, Tipton, and Johnson 2010; Moeyaert et al. 2017). There further is little evidence for the reliability and validity of measurements. These factors could explain the high heterogeneity and bias obtained in the meta-analysis. They also suggest that there is much more to learn about the association between code-related activities and early literacy skills.

It must also be acknowledged that the search terms were limited to the home literacy model (Sénéchal, Whissel, and Bildfell 2017). Future research should include more terms to analyse a greater quantity and diversity of studies.

Moreover, correlational studies cannot determine the directionality of the relationship between two variables (Dancey and Reidy 2017). It is logical to think that code-related activities would impact the development of early literacy skills. However, there is also evidence that suggests that parents adapt to their children's skills and act according to them (e.g., Kim 2007). Therefore, this relationship could be bidirectional.

On the other hand, this study also has important strengths as it helped to fill a gap in literature using rigorous methods. The meta-analysis went beyond the review performed by Sénéchal, Whissel, and Bildfell (2017). It mainly supported their findings, but used more precise methods to calculate the association between code-related activities and literacy skills. The scoping review allowed a thorough characterisation and comparison of the studies. It went beyond just correlation coefficients, and identified more gaps in literature that could be tackled by future studies. This knowledge can be used to design interventions and public policies that target the development of early literacy skills, especially in underprivileged children.

The results of this research have several implications for future research. Firstly, as previously discussed, studies did not report important variables (i.e., SES details, number of languages spoken by children, presence of disabilities and which parent participated in the study). Future research on HLE should endeavour to include complete information about the sample and the participant's background to allow a more meaningful interpretation and comparison of results, especially considering that factors such as SES (Suggate et al. 2018), the number of languages spoken by the child (Kennedy and McLoughlin 2022), and the presence of a disability are factors that have an impact on children's language and literacy development (Graham et al. 2020). There is also evidence that mothers and fathers have a different impact on the HLE and children's language development (Liu and Hoa Chung 2022; Xiao et al. 2020), which could be explored further. Moreover, there is some variability in statistical power across studies, with four studies reporting results from less than 100 participants. Future work should therefore ensure adequate sample sizes to find statistical evidence for the investigated effects.

Secondly, it was found that there is more research on English-speaking participants, from western industrialised countries, and with mothers as the main informants. Consequently, there is a gap in research on other countries (especially from the middle east, Africa and Latin America), languages and other family members, which should be addressed by future studies. Similarly, writing was the least-studied early literacy skill and should be investigated further to build a body of research allowing for a more conclusive evaluation of the link between code-related activities and early literacy skills.

Lastly, even though all analysed studies used questionnaires to collect data, the items they designed and the research and materials they referenced to do so were different. As discussed earlier, studies focused on the frequency of code-related activities of children exclusively with their parents and with a limited number of literacy resources. The focus on traditional literacy resources is highlighted, with new technologies such as computers, mobile phones and tablets being under-researched. This means that the operationalization of code-related activities varies, which could be related to the high heterogeneity obtained in the results of this study. Hence, more thorough research, with a comprehensive operationalization of code-related activities is needed in this field. In other words, code-related activities should be explored thoroughly, in terms of frequency and quality, considering all family members who live with the children, as well as all possible literacy resources. The diary of shared book activities used by Zhang et al. (2020) is an interesting method of data collection that can be replicated in future studies, as it is able to capture not only the frequency, but also the quality of code-related activities, which many studies were not able to do (Sénéchal, Whissel, and Bildfell 2017). It can also be adapted to record all types of literacy resources besides books. However, this method is still affected by parents' bias, which could be addressed by using observational methods (Phillips and Lonigan 2009).

6 | Conclusion

This paper presents a scoping review and meta-analysis of studies that associated code-related activities and early literacy skills, using 18 peer-reviewed papers. It was found that studies varied widely in terms of sample size, participants' sex/gender, SES, native language and country of residence. Most participants spoke English and lived in western, industrialised countries. A large proportion of studies omitted information on whether participating children spoke more than one language, had disabilities and which parent participated. All studies used parental questionnaires to collect data, but their designs were different and focused on limited literacy resources, which may have impacted the studies' outcomes.

The meta-analysis found a small, significant, positive correlation between code-related activities and early literacy skills, high heterogeneity between the studies, and the presence of publication bias. The differences between conceptualizations of code-related activities, participants and study design may explain the high heterogeneity and could be sources of other types of bias. To develop more reliable measures of code-related activities, a comprehensive operationalization of the construct will be required, encompassing different contexts and literacy practices. Researchers in the field of HLE are encouraged to be as thorough as possible when studying code-related activities and to document what they do openly in detail for other researchers to draw on.

Ethics Statement

It received ethical approval from the first author's affiliated institution and did not involve any human or animal participants. No permission to reproduce material from other sources is needed.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

All correspondence concerning this article should be addressed to Isidora Castillo-Rabanal, including the request of data.

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Note: *Studies that were used in the review and meta-analysis. **Studies cited in the HLE and early literacy skills data collection instruments.

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Appendix A

TABLE A1 | Summary of sample sizes and correlations between code-related activities and early literacy skills.

Study citation	Sample size	Letter knowledge	Early reading	Writing
Bojczyk et al. (2015)	112	0.15	0.18	
Foy and Mann (2003)	40	0.29	0.14	
Georgiou, Inoue, and Parrila (2021)	172		−0.08	
Hood, Conlon, and Andrews (2008)	143	0.22	0.28	0.25
Inoue, Georgiou, Muroya, et al. (2018)	142	0.06		−0.02
Inoue, Georgiou, Parrila, et al. (2018)	214	0.37		
Inoue et al. (2020) Dutch sample	120	0.19		
Inoue et al. (2020) English sample	172	0.18		
Inoue et al. (2020) German sample	184	0.01		
Inoue et al. (2020) Greek sample	238	0.23		
Li and Li (2022)	223		0.15	
Liu, Georgiou, and Manolitsis (2018)	132		0.12	
Liu and Hoa Chung (2022)	354		0.08	
Manolitsis, Georgiou, and Tziraki (2013)	82	0.23		
Neumann (2016)	101	0.27		0.27
Silinskas et al. (2012)	1436		0.07	
Strasser and Lissi (2009)	126	0.30		0.19
Van Tonder, Arrow, and Nicholson (2019)	35	0.13	0.31	
Wang and Liu (2021)	194		0.19	
Westerveld et al. (2015)	92	0.42		0.36
Zhang et al. (2020)	159		0.41	

TABLE A2 | Summary of HLE and early literacy measures.

Study citation	HLE measures	Early literacy measures
Bojczyk et al. (2015)	Formal Home-learning activities* Informal Home-learning activities Home-learning environment profile, home-learning experiences subscale Stony Brook family reading survey	Alphabet knowledge* Comprehension of print* Conventions of print Reading quotient (overall)
Foy and Mann (2003)	Teaching frequency* Teaching emphases* Storybook exposure* Parental familiarity Parental reading activities Reading media	Letter knowledge Reading* Expressive vocabulary
Georgiou, Inoue, and Parrila (2021)	Direct teaching* Shared book reading* Access to literacy resources* Reading comprehension activities	Reading accuracy* Phonological awareness Vocabulary Reading comprehension
Hood, Conlon, and Andrews (2008)	Parental teaching* Parental reading	Letter-word identification* Reading rate* Spelling rate* Phonological awareness Receptive vocabulary Reading
Inoue, Georgiou, Muroya, et al. (2018)	Parent teaching* Shared reading*	Character knowledge* Spelling* Reading fluency
Inoue, Georgiou, Parrila, et al. (2018)	Parent teaching* Shared book reading* SES	Letter knowledge* Phonological awareness Vocabulary Naming speed
Inoue et al. (2020)	Parent teaching* Shared book reading Access to literacy resources	Letter knowledge* Spelling* Phonological awareness Vocabulary Reading fluency
Li and Li (2022)	Home reading* resources Parent reading instruction* Children's interest in print	Chinese Word reading*
Liu, Georgiou, and Manolitsis (2018)	Formal home literacy experiences* Informal home literacy experiences* Literacy resources at home*	Reading (character recognition)* Vocabulary Phonological awareness
Liu and Hoa Chung (2022)	Direct teaching* Shared book reading* Access to literacy resources* Parental expectations	Word reading* Phonological awareness Orthographic awareness RAN Vocabulary
Manolitsis, Georgiou, and Tziraki (2013)	Parent literacy teaching* Storybook exposure*	Letter knowledge* Vocabulary Initial sound identification Syllable segmentation
Neumann (2016)	Storybooks owned* Storybook-reading* Alphabet resources* Parent literacy teaching*	Letter name* Letter sound knowledge* Name writing* Print concepts
Silinskas et al. (2012)	Shared reading* Teaching of reading (mother and father)*	Word reading* Reading (kindergarten)*

(Continues)

TABLE A2 | (Continued)

Study citation	HLE measures	Early literacy measures
Strasser and Lissi (2009)	Home letter-teaching* Home book exposure*	Letter identification* Emergent writing* Alphabet knowledge Phonemic awareness Receptive vocabulary
Van Tonder, Arrow, and Nicholson (2019)	Shared storybook reading* Number of books in the home* Word games* Alphabet teaching* Talking about what you read*	Letter sound knowledge Early word reading Receptive vocabulary Phonological awareness
Wang and Liu (2021)	Informal HLE (shared book reading and shared storytelling)* Formal HLE (teach child to write characters, teach child to read) Access to literacy resources*	Character reading* Reading fluency
Westerveld et al. (2015)	Times children are read to Number of books at home Parent teaching* Child asks to be read to	Story retelling and comprehension Letter knowledge* Initial phoneme identification Name writing*
Zhang et al. (2020)	Formal HLE (frequency of teaching to read Chinese characters, frequency of teaching pinyin, frequency of teaching to write Chinese characters)* Informal HLE (frequency of reading a story to child at bedtime, frequency of reading story to child at other times)* Access to literacy resources*	Pinyin knowledge* Vocabulary Phonological awareness Rapid automatized naming

*Measures that correspond to Sénéchal, Whissel, and Bildfell (2017) HLE model.

TABLE A3 | Summary of HLE and early literacy instruments.

Study citation	HLE instrument	Early literacy skills instruments
Bojczyk et al. (2015)	Questionnaires (based on Heath, Levin, and Tibbetts 1993; Stipek et al. 1992; Whitehurst 1992)	TERA-3 alphabet and TERA-3 meaning (Reid, Hresko, and Hammill 2001)
Foy and Mann (2003)	Questionnaire (Sénéchal et al. 1998) Children's Author Checklist and Children's Title Checklist (Sénéchal et al. 1996)*	Concepts about Print Test (Clay 1979) Word identification and Word attack subtests of the Woodcock Reading Mastery Test (Woodcock 1987)
Georgiou, Inoue, and Parrila (2021)	Questionnaire (based on Kirby and Hogan 2008; Sénéchal 2006; Stephenson et al. 2008)	Word identification and Word attack subtests of the Woodcock Reading Mastery Test—Revised (Woodcock 1998)
Hood, Conlon, and Andrews (2008)	Questionnaire (based on Foy and Mann 2003; Sénéchal et al. 1998) Title Recognition Test (derived from Angus and Robertson 1999, as cited in Hood, Conlon, and Andrews 2008)	Letter–Word Identification subtest of the Woodcock Diagnostic Reading Battery (Woodcock 1997) A list based on the most frequent English words from Dolch's (1936) and Kucera and Francis's (1967)
Inoue, Georgiou, Muroya, et al. (2018)	Questionnaire (based on Hood, Conlon, and Andrews 2008; Kirby and Hogan 2008; Sénéchal 2006)	Hiragana knowledge test and Hiragana spelling test (Inoue et al. 2017)
Inoue, Georgiou, Parrila, et al. (2018)	Questionnaire	Letter Identification Task (Clay 1993)
Inoue et al. (2020)	Questionnaire	Uppercase letters on A4 paper. Existing spelling to dictation task in each language (English: Wechsler 2001; Dutch: Geelhoed and Reitsma 1999; German: Moll and Landerl 2010; Greek: Mouzaki et al. 2007).
Li and Li (2022)	Questionnaire (based on Justice et al. 2016; Liu, Georgiou, and Manolitsis 2018; Martini and Sénéchal 2012; Sénéchal 2006; Sénéchal and LeFevre 2002)	Chinese character recognition task (Chow et al. 2008)
Liu, Georgiou, and Manolitsis (2018)	Questionnaire (based on McBride-Chang et al. 2012)	Character recognition (Li et al. 2012)
Liu and Hoa Chung (2022)	Questionnaire (based on Georgiou, Inoue, and Parrila 2021; Sénéchal 2006)	One- and 2-character words used in previous studies (e.g., McBride-Chang and Ho 2000) were combined with the Chinese word reading subtest of the Hong Kong Test of Specific Learning Difficulties in Reading and Writing (Ho et al. 2000)
Manolitsis, Georgiou, and Tziraki (2013)	Questionnaire (based on Stephenson et al. (2008)	24 uppercase and lowercase Greek letters on A4 paper.
Neumann (2016)	Questionnaire (based on Sénéchal et al. 1998).	Upper-case letters on cards. A 7-point rating scale adapted from Bloodgood (1999) was used to score name writing
Silinskas et al. (2012)	Questionnaire (based on Sénéchal et al. 1998)	Individually administered wordlist (subtest of ARMI; Lerkkanen, Poikkeus, and Ketonen 2006)
Strasser and Lissi (2009)	Questionnaire	29 lowercase letters. Write their own name and three additional words—Mesa (table), Camión (truck), and Plátano (banana)
Van Tonder, Arrow, and Nicholson (2019)	Questionnaire (based on Teale and Sulzby 1986)	YARC Letter sound knowledge YARC Early word recognition (Hulme et al. 2012)
Wang and Liu (2021)	Questionnaire (based on Martin, Mullis, and Kennedy 2007).	100 Chinese characters, which were arranged in order of ascending difficulty (McBride-Chang et al. 2003).
Westerveld et al. (2015)	Questionnaire (based on Boudreau 2005, and van Bysterveldt, Gillon, and Foster-Cohen 2010).	Letter-knowledge task (Carson, Gillon, and Boustead 2011) Name writing task (scoring procedure based on Cabell et al. 2009)
Zhang et al. (2020)	Questionnaire Diary with daily book shared activity (adapted from Anderson, Wilson, and Fielding 1988; Allen, Cipielewski, and Stanovich 1992)	Pinyin letter and syllable knowledge task (Li et al. 2017). Character Recognition (Li et al. 2012)

TABLE A4 | Summary of type of study, HLE instruments used to collect data, early literacy measures and literacy resources, according to studies.

Study citation	Type of study	HLE instrument	Early literacy measures	Literacy sources
Bojczyk et al. (2015)	Cross-sectional	QB	Letter Knowledge Early reading	Flashcards or workbooks Labels Books Library visits
Foy and Mann (2003)	Cross-sectional	QB Children's Author Checklist and Children's Title Checklist*	Letter knowledge Early reading	Storybooks Library visits Pictures TV or videos Educational computer programs
Georgiou, Inoue, and Parrila (2021)	Longitudinal	QB	Early reading	Books Children's books
Hood, Conlon, and Andrews (2008)	Longitudinal	QB Title Recognition Test	Letter knowledge Early reading Writing	Children's books Library visits
Inoue, Georgiou, Muroya, et al. (2018)	Longitudinal	QB	Letter knowledge Writing	NS
Inoue, Georgiou, Parrila, et al. (2018)	Longitudinal	Questionnaire	Letter knowledge	Children's books
Inoue et al. (2020)	Longitudinal	Questionnaire	Letter knowledge Writing	Children's books Adult books
Li and Li (2022)	Cross-sectional	QB	Early reading	Children's books Print in daily life Print in media
Liu, Georgiou, and Manolitsis (2018)	Cross-sectional	QB	Early reading	Children's books
Liu and Hoa Chung (2022)	Cross-sectional	QB	Early reading	Books
Manolitsis, Georgiou, and Tziraki (2013)	Longitudinal	QB	Letter knowledge	Children's books
Neumann (2016)	Cross-sectional	QB	Letter knowledge Writing	Storybooks Alphabet resources (charts/posters, magnetic letters, flashcards)
Silinskas et al. (2012)	Longitudinal	QB	Early reading	Books
Strasser and Lissi (2009)	Longitudinal	Questionnaire	Letter knowledge Writing	Storybooks Children's books Places where they purchased books
Van Tonder, Arrow, and Nicholson (2019)	Cross-sectional	QB	Letter knowledge Early reading	Storybooks Books Word games Tablet Smartphone
Wang and Liu (2021)	Cross-sectional	QB	Early reading	Books Literacy resources
Westerveld et al. (2015)	Cross-sectional	QB	Letter knowledge Writing	Children's books Picture books Library visits
Zhang et al. (2020)	Longitudinal	Questionnaire Diary with daily book shared activity	Letter knowledge	Books

Note: N = 18 studies.
Abbreviations: NS, not specified; QB, questionnaire based on other authors.
*Used to measure meaning-related activities.