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A systematic literature review of math interventions across educational settings from early childhood education to high school

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Early math skills lay the foundation for children's long-term academic success. An increasing number of randomized controlled math interventions have been carried out across educational settings. The aim of the present systematic review was to identify the distribution of the randomized controlled math interventions conducted between 2001 and 2021 in educational settings across Early Childhood Education (ECE) up to high school among various sample types, and to describe their central features at each educational setting separately. Based on the knowledge gaps exposed through the systematic review, we aimed to discuss where and how future math interventions are still needed in order to optimize all children's math skill development across educational settings and sample types from early on. A total of n=75 math interventions meeting the inclusion criteria using the PRISMA-guidelines were identified, of which the majority of them were executed in the elementary school, mostly targeting at-risk children. It is proposed that there is still a large potential of promoting children's math skills from early on in the ECE settings, utilizing both teachers and parents, among at-risk *and* non-at-risk samples.

KEYWORDS

math intervention, early interventions, systematic review, math education, stem education

1 Introduction

Mathematical skills play an important role in adults' every-day lives, whether in relation to mundane activities such as shopping for groceries or in relation to more complex tasks such as understanding interest rates, managing personal finances, or doing taxes. Mathematical skills are known to be strongly associated with, and form the basis of, successful careers and high earnings (Duncan et al., 2007; Joensen and Nielsen, 2009, 2016; Cortes et al., 2015). At the same time, poor math skills—even to a higher degree than poor reading skills—are linked to inferior educational and labor market opportunities, increased rates of unemployment, health issues, and criminality (Parsons and Bynner, 1997; Geary, 2011). In light of the increasing number of STEM-related jobs in the modern societies, practitioners and policy makers highlight the need for more knowledge of how to best promote children's mathematical skills from early on (Zollman, 2012). In fact, improving math skills does not only enhance an individual's opportunities for success in life, but is equally likely to decrease the negative economic consequences of poor math skills for society as a whole (Parsons and Bynner, 1997; Evans and Field, 2020).

Moreover, children's early math skills are a strong predictor of their later math skills and academic achievement more broadly (Duncan et al., 2007). Growing evidence supports the claim that math skills should be promoted from early on to optimize children's mathematical learning potential over time (Clements and Sarama, 2011; Siegler and Braithwaite, 2017). An abundance of previous systematic reviews and meta-analyses have been conducted during the past decades summarizing the main findings of math interventions focusing on children at a specific educational setting (e.g., high school) or on children at-risk (e.g., for learning or math difficulties). However, it is still unclear whether the explicit focus on these sample types reflects the aim of the previous reviews or the abundance of previous math interventions targeting these specific samples (or both). Therefore, the aim of the present systematic review was to identify and to describe the central features of a broader range of randomized controlled mathematic interventions conducted among 0–16-year-old children across educational settings from Early Childhood Education (ECE) to high school, and across at-risk and non-at-risk samples. By mapping the existing landscape of math interventions across the broad range of educational settings and sample types, we also aimed to discuss the potential knowledge gaps in the existing math intervention literature in terms of their potential of benefiting all children's math acquisition from early on.

1.1 What are math skills and how do they develop over time?

Mathematical skills cover a variety of skills ranging from simple numeracy skills (e.g., oral counting), to abstract skills (e.g., patterning) and to specific operations (e.g., arithmetic) for solving mathematical problems (LeFevre et al., 2010; Adler, 2017; Lindenskov and Weng, 2018). The development of mathematical understanding, and the acquisition of specific math skills follow a sequential pattern with early skills begetting later skills in close interaction with other fundamental cognitive skills (Phillips and Shonkoff, 2000; Duncan et al., 2007). Even small infants possess a rudimental understanding of magnitudes and simple arithmetic (Dehaene, 2011). However, first in the preschool years, children undergo fundamental developments in numerical understanding, referred to as "early numeracy," which lay the foundation for subsequent, more complex, mathematical operations (e.g., addition, substraction, Gelman and Gallistel, 1978; Perna and Loughan, 2014; Siegler, 2016, 2020; Siegler and Braithwaite, 2017). In particular, between the ages 3–5, children acquire a basic understanding of the one-to-one principle (i.e., each unit is only counted once), the order principle (i.e., the number words are produced in a certain order and in the same set order each time), and the cardinal principle (i.e., the value of the last counted unit is the value for the whole set, Gelman and Gallistel, 1978). From first grade onwards, children gradually use various arithmetic strategies, and they use simple operations (addition and subtraction) to learn more complex operations (multiplication and division). Although children's understanding of fractions improves from 11 years onwards, fraction understanding remains challenging for many college students and adults (Siegler et al., 2011; Siegler and Lortie-Forgues, 2015).

Children's knowledge of numbers in kindergarten has been shown to predict their math achievement years later in elementary, middle, and high school (Watts et al., 2014, 2015). Geary et al. (2017) demonstrated that children with an earlier understanding of the cardinality principle in the preschool years, had better math skills when starting in the first grade, even after controlling for intelligence, executive functions, and parents' education level. Furthermore, a basic understanding of numerical magnitudes, i.e., understanding of how numbers represent the correct magnitude of objects, items, and events, has been shown to be an important prerequisite of mathematical knowledge and achievement over time (Booth and Siegler, 2008; Siegler and Braithwaite, 2017). Therefore, children's early understanding of numbers and magnitudes appear to have long-term implications for children's math skills in particular, and for academic achievement in general.

Math skills have been shown to be closely related to other important academic skills, such as executive functions (Clark et al., 2013; Cameron et al., 2019; Simanowski and Krajewski, 2019), and language skills (Peng et al., 2020). While some studies have indicated that children's early math skills predict their later reading skills (Duncan et al., 2007), other studies have suggested that early reading skills predict higher math achievement over time (Bailey et al., 2020; Hübner et al., 2022). Moreover, children's early language skills have been linked to their early numeracy knowledge (Purpura and Reid, 2016). Overall, these findings suggest that children's language and math skills are interchangeably connected with each skill supporting one another (Peng et al., 2020).

1.2 Previous reviews of math intervention studies

Due to the large number of primary studies, numerous systematic reviews and meta-analyses of math interventions have been conducted during the past decade with each review focusing on specific target groups at various ages and/or skill levels. As the previous meta-analysis have focused on different moderating factors contributing to the main effects of the interventions, with each previous intervention targeting a specific group of students, a coherent synthesis of the effective content elements of the previous math interventions is challenging. Therefore, in the following, only the main tendencies and effects are outlined.

A systematic review of early numeracy interventions among 4—7-year-old children at risk for mathematic difficulties indicated that children receiving early numeracy interventions outperformed children in the active control group, with a mean effect size of $g = 0.76$ (Mononen et al., 2014). A meta-analysis of the effectiveness of 29 early mathematics interventions in prekindergarten and kindergarten programs found an average effect size of $d = 0.62$ across all programs, with programs designed for the pre-K environment showing larger effects than those designed for kindergarten, and programs presenting single content (e.g., numbers and operations) to individual children showing largest effects (Wang et al., 2016). None of the previous reviews have included math interventions in the infant-toddler ECE settings.

Meta-analyses and systematic reviews of math interventions conducted in the elementary school setting (Grades 1–5) have mainly focused on interventions targeting students with (or at risk for) math or academic difficulties (Dietrichson et al., 2021; Myers et al., 2022), students with special educational needs (Kroesbergen and Van Luit, 2003), or students with intellectual disabilities (Schnepel and Aunio, 2022). The average effect sizes across math interventions targeting at-risk students in the elementary school have ranged from small to medium to large (*ESs* = 0.27–0.81). While Dietrichson et al. (2021) found larger effects for interventions focusing on peer-assisted instruction and small group instructions, Myers et al. (2022) found larger effects for interventions implemented in large groups for students with math difficulties. Larger intervention effects were also found when the interventions involved explicit and systematic instruction of math in one-on-one, or small groups for students with educational difficulties (e.g., Schnepel and Aunio, 2022). Moreover, other meta-analyses and reviews within the elementary school setting have focused on interventions aiming at improving specific mathematical target skills, such as addition and subtraction (Methe et al., 2012) or fraction understanding (Roesslein and Codding, 2019), or they have aimed at investigating improvement of math skills at an individual student level (i.e., single-case studies, Burns et al., 2010; Codding et al., 2011).

Meta-analyses and systematic reviews focusing on secondary and middle school students have mainly centered around math interventions targeted at students with math difficulties (Stevens et al., 2018; Schumacher et al., 2020; Myers et al., 2021; Powell et al., 2021) or at students with emotional problems (Losinski et al., 2019). Overall, these interventions have shown significant positive effects on secondary school students' math skills with moderate average effect sizes (*ES*s = 0.49–0.65).

Lastly, several meta-analyses and systematic reviews have included math interventions across educational settings, for instance across kindergarten, elementary and middle school (i.e., K-12; Zhang and Xin, 2012; Lein et al., 2020; Ran et al., 2021; Dennis et al., 2022), across elementary and middle or high school (Templeton et al., 2008; Aspiranti and Larwin, 2021; Peltier et al., 2021), or across middle and high school (Jitendra et al., 2018; Zhang et al., 2022). In these reviews, larger effects were found for interventions conducted in the elementary grades than in higher grades, and for interventions developed and implemented by the researchers (Lein et al., 2020). Only three meta-analyses have included math interventions involving students from preschool to high school (Jitendra et al., 2021; Nelson et al., 2022; Williams et al., 2022). These meta-analyses suggested that interventions implemented in small groups were more effective (Jitendra et al., 2021), and that interventions conducted by researchers and teachers were similarly effective (Williams et al., 2022).

Despite the substantial number of reviews of math interventions across several educational settings and age groups, the large majority of them have focused on low performing students (Ran et al., 2021; Dennis et al., 2022), on students with psychological disorders (Templeton et al., 2008; Peltier et al., 2021; Zhang et al., 2022), or on students with math or learning difficulties (Zhang and Xin, 2012; Jitendra et al., 2018; Lein et al., 2020; Jitendra et al., 2021; Nelson et al., 2022). Meta-analyses focusing on these specific target groups of students reported overall positive, small to moderate effect sizes (*E*Ss = 0.37–0.56). The intervention effects were generally larger for younger compared to older age groups, thus reflecting the general tendency of children in the lower grades having higher achievement growth compared to children in the higher grades (Bloom et al., 2008).

Only one meta-analysis by Williams et al. (2022) has included math interventions conducted across preschool to high school settings and has focused on universal as well as targeted interventions with children from various sample types (see also Jitendra et al., 2021 and Nelson et al., 2022 for a broader age group, but with focus on interventions for students with learning or math difficulties). Williams et al. (2022) found an average effect of $g = 0.31$ on student math achievement with a wide range of intervention effects. For instance, teacher- and interventionist-delivered programs ($g = 0.37$ and $g = 0.39$, respectively) had average effects that were about three times as large as effects from technology-delivered programs ($g = 0.12$). Also, supplemental time interventions had larger average effects ($g = 0.53$) than curriculum-based interventions ($g = 0.34$) or instructional/pedagogical interventions ($g = 0.27$). However, the meta-analysis by Williams et al. (2022) only included interventions conducted in the United States (US). Furthermore, the broad scope of their meta-analysis prevented a more fine-grained coding of the intervention details, thus resulting in broad estimates of effectiveness of intervention elements across the age groups, rather than detailed descriptions of math interventions at each educational setting.

Hence, although a substantial number of reviews of math interventions have been conducted in the past, most of them have comprised of so-called Tier 2 or Tier 3 interventions (Ontario Ministry of Education, 2005), which target children needing additional support or having academic difficulties in a group format (Tier 2) or through individualized instruction (Tier 3, Harlacher, 2023). The question rises whether the abundance of review literature on Tier 2 or 3 math interventions reflects the overall number of math interventions conducted for this target group, or purely the specific focus of the reviews. Moreover, although some meta-analyses have included math interventions across a broad range of educational settings (e.g., Williams et al., 2022), none of them have specified features of math interventions at each education setting separately. By now, there is thus rich evidence indicating that math interventions targeting lower performing children or children at risk are effective at improving children's math skills. However, there is still a need for a systematic review mapping the landscape of math interventions targeting both at-risk and non-at-risk children across educational settings.

1.3 The aim of the present systematic review

The present systematic review had three overarching aims. First, we aimed to *identify* the broad landscape of randomized controlled math interventions specifically aiming at improving children's math skills, across the ECE programs (i.e., infant-toddler classrooms, preschool) to high school. Our focus on the educational settings involving 0–16-year-old children was motivated by the lack of previous reviews on this broad age range, as well as by the growing evidence highlighting the importance of promoting children's math skills (as well as other academic skills) from early on (Clements and Sarama, 2011; Duncan et al., 2022). Furthermore, we focused exclusively on math interventions using randomized controlled designs, including both a control and a treatment group, as the randomized controlled design is the most rigorous way of determining whether there is a cause-effect relationship between the intervention and the outcome (Kendall, 2003). However, we focused only on math interventions examining short-term effects on math related outcomes.

Second, we aimed to *describe* the features of the identified math interventions at each educational setting in terms of what types of math interventions have been conducted, who has implemented the math interventions (e.g., a researcher, a teacher), what sample types and sizes of samples the interventions are based on, for how long the interventions have lasted, and in which format they have been conducted. By describing the main features of the existing math interventions at each educational setting separately, educators and practitioners may be informed about the central features of math interventions at the educational setting of their interest.

Third, we aimed to *discuss* the potential knowledge gaps exposed through the systematic review in terms of where future math interventions are still needed in order to gather more knowledge on how to improve *all* children's opportunities, across educational settings and sample types, for learning math from early on. Ultimately, identification of existing knowledge, as well as knowledge gaps in the math intervention literature, may be beneficial for researchers and practitioners in developing future math interventions, which may—in the long rung—be applicable and scalable to *all* children across educational settings and across sample types. Given the documented long-term effects on math skills for both individuals (Geary, 2011) and society (Evans and Field, 2020), the potential of applying math-focused interventions to all children, can probably not be exaggerated.

2 Methods

2.1 Search procedure, literature databases, and search string

The systematic review process was conducted based on the PRISMA-guidelines (Page et al., 2021) in order to identify empirical studies of high-quality math interventions. A systematic electronic search of articles was conducted using the databases ProQuest, EBSCO-host, Scopus, Web of Science, and JSTOR in October 2021. After several trial searches, the following search string resulted in the most accurate search results: (math OR math* OR mathemat* OR mathematical OR mathematics) AND (Intervention*) AND (RCT OR "randomi$ed. control* trial*" OR "randomi$ed. control* study" OR "randomi$ed. study" OR "randomi$ed. trial" OR "randomi$ed. social experiment"). The search string yielded in a total of $n = 2,308$ article across databases.

2.2 The inclusion and exclusion criteria

Inclusion/exclusion criteria were used during the title/abstract and full-text screening phase for all identified records in the databases ($n = 2,094$ after removing duplicates). To be included in the present systematic review, a primary study had to satisfy the following eligibility criteria: (1) the study was published in English in a peer-reviewed journal during the last 2 decades (2001–2021); (2) the main aim of the intervention was to improve children's math skills, competences, or achievement as their primary outcome alone or together with other (academic) skills (e.g., language); (3) the study used experimental randomized designs involving a control and a treatment group; (4) the study included a sample of typically developing children within the age range of 0–16 years old; (5) the study was conducted either in the ECE setting, in the school (primary/secondary) setting or at home; (6) the study included at least one quantitative outcome related to children's math skills, competences, or achievement. The studies were excluded if they were qualitative studies, reviews, meta-analyses, and/or case-studies; if the main aim of the intervention was to promote something else than math skills as their primary outcome (e.g., mind-set, beliefs, and physical shape) and where the math skills were only included as a distal or secondary outcome; if they were reported in book chapters, dissertations, reports, working papers, or government publications; and if they were targeted children with identified neurodevelopmental disorders (e.g., autism spectrum disorder, Down Syndrome, and ADHD), or other disabilities that are clinically diagnosed (also included preterm born children).

2.3 Screening and data extraction

The initial phase of reviewing entailed the abstract/title screening in the review management software "Covidence." By means of the eligibility criteria, studies could be either included or excluded after reading the title and abstract of a study. The abstract/title screening was followed by the full-text screening phase. Following the full-text screening, a total of $n = 75$ studies were included in the data extraction phase, where an existing coding scheme that administered RCT studies was adapted to extract (a) descriptive information of the study (e.g., location, setting, participant characteristics etc.), (b) intervention implementation (e.g., materials and tools, format, instructor, intensity, duration, dosage etc.), and (c) study results (e.g., outcome measures, instruments, findings, effective mechanisms, and moderator/subgroups). The number of studies identified, included, and excluded are reported in the PRISMA flowchart depicted in the Figure 1.

2.4 Reliability of screening

Prior to the abstract/title and full-text screening, three research assistants were trained and required to achieve at least 80% or higher interrater agreement with the first two authors who acted as master coders throughout the screening and coding process. Fifteen percent (15%) of all studies in the abstract/title and in the full-text screening phases, respectively, were double-coded by the student assistants and by one of the master coders. The interrater agreement was 97.5% in the abstract/title screening phase, and 91.7% in the full-text screening phase. Conflicts were resolved by the first two authors in the full-text screening phase if studies were registered as both included and excluded by different screeners, or if they were excluded for conflicting reasons.

2.5 Data synthesis

A mutually exclusive and exhaustive coding system was created for the purpose of data synthesis of $n = 75$ articles, from which information was extracted during the data extraction phase.

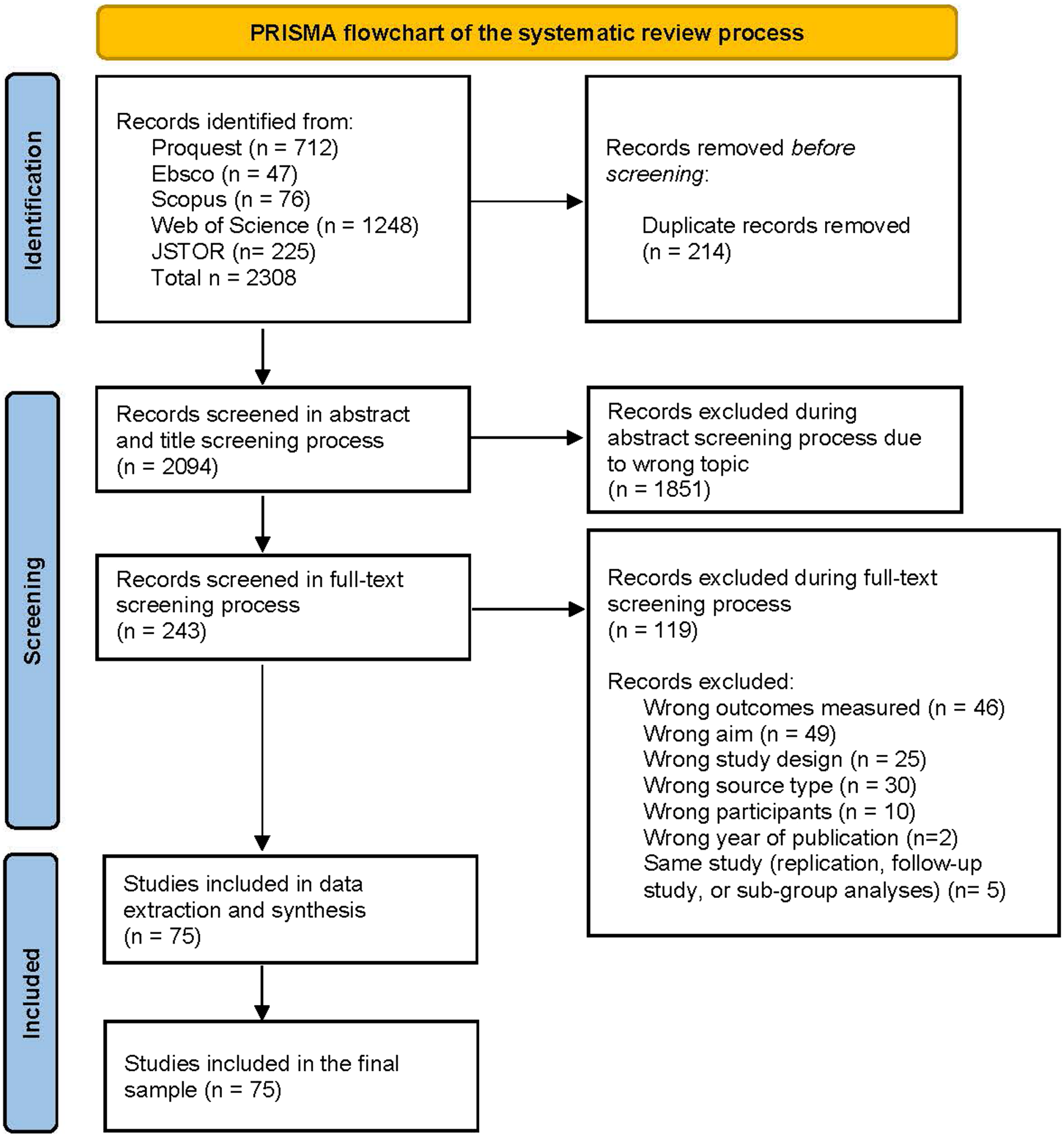

FIGURE 1
The PRISMA flowchart of the data screening procedure.

2.5.1 The main target of the intervention

Interventions were coded based on whether they focused (1) on improving children's math skills, or (2) on improving children's math skills among other (academic) skills (e.g., reading, working memory, executive functioning etc.).

2.5.2 Interventions across the educational settings

Interventions were categorized by participants' education setting in (1) daycare (0–2-year-old), (2) preschool (3–5-year-old), (3) kindergarten (5–6-year-old), (4) elementary school (1st–5th grade; 6–10-year-old), (5) middle-school (6–8th grade; 11–13-year-old), and (6) high school (9–12th grade; 13–16-year-old). If the intervention lasted for a longer period, the code in this category was given by the lowest education level mentioned as that is when the intervention began. The coding related to the education levels (participants by grades and ages) took the point of reference in the United States education system, as most of the included studies originated from the United States.

2.5.3 Sample sizes and characteristics

The sample sizes were identified per math intervention in terms of the total sample size per treatment and control group, respectively. The sample characteristics were categorized as (1) an unspecified, non-at-risk sample, (2) an environmental at-risk sample [children from low socio-economic status (SES) and/or from diverse ethnic backgrounds or foster families], (3) a sample with special educational needs (e.g., learning problems), and (4) a sample with low initial math skills or at-risk for math difficulties.

2.5.4 The intervention types

Interventions were categorized as (1) professional development/coaching, where the interventions focused on improving the teachers' ability to promote children's math skills, (2) curriculum-based interventions which followed a specifically designed (math-related) curriculum (e.g., the ROOTS, the Building Blocks) involving lesson plans, materials, and activities aligned with the goals of the interventions, or as (3) supplemental time interventions, which were "add-ons" to standard math-related curriculum and to instructional activities, such as tutoring, double-periods, afterschool classes, or inclusion of an additional math-related element to normal teaching (such as mindfulness or use of iPads along normal teaching). Since many of the interventions included both curriculum-based elements but were at the same time conducted as a supplemental time or as an add-on to normal teaching, interventions could also be categorized as (4) a combination of curriculum-based and supplemental time/add-on intervention types. Many interventions were based on the use of a specific curriculum but included professional development or coaching, and these were coded as (5) a combination of curriculum-based and professional development or coaching.

2.5.5 Who implemented the intervention?

The interventions could be implemented either by (1) teachers, (2) parents, (3) tutors (e.g., peers or older students), (4) both teachers and parents, (5) research assistant/intervener specifically hired for the intervention, (6) other (e.g., government, principals, assistants, and consultants), or (7) no information was provided.

2.5.6 Duration

The duration of the intervention was determined as lasting for (1) less than a month, (2) between 1 and 6 months/one semester, (3) 1 year, (4) 1–2 years, (5) over 2 years, and (6) no information.

2.5.7 Format

The activities related to the intervention were carried out (1) individually, (2) in classrooms, (3) in small groups or pairs, (4) a combination of individual, classroom, or small groups, or (5) no information was provided about the format.

2.5.8 Math outcome measures

Up to 10 math related outcomes could be measured as immediate outcomes of the interventions, which were each categorized as (1) general math grade at school, (2) a composite math score of math achievement/skills (e.g., Woodcock Johnson, Wechsler, SAT, EGMA, TEMA, TEDI-MATH, TEAM, REMA, a researcher developed summary score of different math skills), (3) number sense/numeracy and arithmetic (addition, subtraction, multiplication, and division), (4) math language, (5) algebra, pre-algebra, (6) fraction understanding and rational numbers, (7) calculation, or (8) geometry, shapes, measuring.

2.5.9 Evidence of intervention effectiveness

Interventions were evaluated based on whether they showed a main effect (e.g., Cohens d or η^2) on at least one math related outcome (significance level of $p < 0.05$) or not, i.e., whether the interventions showed a minimum level of effectiveness. Note that it was beyond the scope of the present review at code whether the interventions showed long-term effects due to the large heterogeneity of the studies, and therefore, the evidence of intervention effectiveness is based on immediate effects of the intervention.

2.5.10 Quality assessment

The quality of the included studies was examined by means of an adapted version of the Cochrane Revised Tool to Assess Risk of Bias in Randomized Trials (RoB 2; Higgins et al., 2011; Sterne et al., 2019). Of the original RoB 2, a set of six points of attention were derived and transformed into indicators that matched the technical level of the student assistants in interpreting and extracting information about risk of bias. The six indicators included: (1) the reported internal validity of instruments [*was (alpha) test reliability reported for the instrument(s)?*], (2) instrument standardization [*were administered instruments standardized, researcher-developed, or other (developed by teachers/schools?)*], (3) differences at baseline [*were there baseline differences between control and treatment group(s)?*], (4) blinding of participants (*were participants aware of their assigned intervention during the trial?*), (5) attrition [*was attrition in the study between the two time points (pre and post) below 20%, between 21 and 40% or higher?*], and (6) randomization [*were participants assigned to treatment at random?* (i.e., *every member and set of members had an equal chance of being assigned to the treatment group*)]. The categories of indicators were translated to "low risk," "some concerns," and "high risk." For example, if test reliability was reported, this indicated a "low risk," no reporting indicated a "high risk," and if studies provided ambiguous information, the student assistants could evaluate the indicator with "Do not know" which was translated into "some concerns." The middle categories of the second and fifth indicator, researcher-developed instruments and reported attrition between 21 and 40%, were also converted into "some concerns" for risk of bias. An overall score of quality for each study was generated by adding up the evaluations on each six indicators (10: low risk, 5: some concerns, and 0: high risk), which resulted in a scale ranging from 0 to 60.

2.5.11 Reliability of data synthesis

The coding system for synthetizing information from the articles included in the present review was developed and adjusted by the first author, who acted as the master coder throughout the data synthesis. The codes were continuously adjusted based on the extracted data from the articles and on the discussions in the author group. Twenty percent (20%) of the articles included in the data synthesis were double-coded by either the second author or by a trained student assistant. The interrater agreement ranged between $\kappa = 0.660$ and 1.00, with a mean $\kappa = 0.79$ across the coding categories, and the agreement therefore ranged from substantial to almost perfect. Disagreements were solved by discussion between the coders.

3 Results

In the following, a general descriptive analysis, using counts and percentages, was conducted to describe the features of the interventions at each educational setting. Table 1 provides an overview of the math interventions included in the present systematic review based on all the synthetized coding categories across the educational settings.

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TABLE 1 Overview of the included math interventions per educational settings.

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Daycare (0–2 years old), *n* = 1										
Bleses et al. (2021)	Daycare	Math + Other	*N* = 538/578	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1–6 months	Combined small/large groups	Yes	40
Preschool (3–5 years old), *n* = 16										
Barnes et al. (2016)	Preschool	Math + Other	*N* = 361/180	Low math skills	Curriculum	Tutor	1–6 months	Small groups	Yes	45
Blair and Raver (2014)	Preschool	Math + Other	*N* = 443/316	Environmental at-risk	Curriculum	Teacher	1–2 years	Small groups	Yes	55
Clements and Sarama (2008)	Preschool	Math	*N* = 101/152	Unspecified non-at-risk sample	Curriculum	Teacher	1–6 months	Small groups	Yes	40
Clements et al. (2011)	Preschool	Math	*N* = 927/378	Environmental at-risk	Curriculum + Prof. Dev.	Teacher	1–2 years	Combined small/large groups	Yes	40
Clements et al. (2020)	Preschool	Math + Other	*N* = 3,683/365	Environmental at-risk	Curriculum + Prof. Dev.	Teacher	1–2 years	Combined small/large groups	Yes	45
Fantuzzo et al. (2011)	Preschool	Math + Other	*N* = 1,415/–	Environmental at-risk	Curriculum + Prof. Dev.	Teacher + Parent	1 year	Combined small/large groups	Yes	45
Fazzio et al. (2021)	Preschool	Math + Other	*N* = 649/1,463	Environmental at-risk	Curriculum + Prof. Dev.	Teacher	1–2 years	No Info	Yes	45
Griffith et al. (2019)	Preschool	Math + Other	*N* = 11/11	Environmental at-risk	Supplemental/Add-on	Parent	1–6 months	Individual	Yes	60
Hawes et al. (2020)	Preschool	Math	*N* = 20/23	Unspecified non-at-risk sample	Supplemental/Add-on	Teacher	<1 month	Small groups	Yes	35
Lonigan et al. (2015)	Preschool	Math + Other	*N* = 760/–	Environmental at-risk	Curriculum + Prof. Dev.	Teacher	1 year	Small groups	Yes	55
Raudenbush et al. (2020)	Preschool	Math	*N* = –/–	Environmental at-risk	Prof. Dev.	Teacher	1 year	Small groups	Yes	30
Rosenfeld et al. (2019)	Preschool	Math	*N* = 307/659	Environmental at-risk	Curriculum + Supplemental/ Add-on	Teacher	1–6 months	Classroom	Yes	50
Schacter et al. (2016)	Preschool	Math	*N* = 50/50	Environmental at-risk	Supplemental/Add-on	Researcher	1–6 months	Individual	Yes	45

(Continued)

TABLE 1 (Continued)

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Schenke et al. (2020)	Preschool	Math	N = 66/33	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	Teacher + Parent	<1 month	Individual	Yes	40
Schmitt et al. (2018)	Preschool	Math + Other	N = 34/35	Unspecified non-at-risk sample	Supplemental/Add-on	No Info	1–6 months	Small groups	No	35
Wakabayashi et al. (2020)	Preschool	Math	N = 323/360	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1 year	Classroom	Yes	45
Kindergarten (5–6 years old), *n* = 10										
Clarke et al. (2017)	Kindergarten	Math	N = 415/177	Unspecified non-at-risk sample	Curriculum	Researcher	1–6 months	Small groups	Yes	40
Foster et al. (2018)	Kindergarten	Math	N = 478/496	Environmental at-risk	Curriculum	Researcher	1–6 months	Individual	Yes	60
Harper and Schmidt (2012)	Kindergarten	Math + Other	N = 33/35	Environmental at-risk	Curriculum + Supplemental / Add-on	Other	1–6 months	Small groups	Yes	45
Jordan et al. (2012)	Kindergarten	Math	N = 88/44	Environmental at-risk	Curriculum	Researcher	1–6 months	Small groups	Yes	55
O'Connor et al. (2014)	Kindergarten	Math + Other	N = 225/210	Environmental at-risk	Curriculum + Prof. Dev.	Teacher + Parent	1–6 months	Combined small/large groups	Yes	55
Outhwaite et al. (2019)	Kindergarten	Math	N = 305/156	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	Teacher	1–6 months	Combined small/large groups	Yes	45
Praet and Desoete (2014)	Kindergarten	Math	N = 83/49	Unspecified non-at-risk sample	Supplemental/Add-on	Researcher	1–6 months	Individual	Yes	55
Shanley et al. (2019)	Kindergarten	Math	N = 203/87	Special educ. needs	Curriculum	Researcher	1 year	Combined small/large groups	Yes	55
Thomas et al. (2018)	Kindergarten	Math	N = 687/686	Environmental at-risk	Curriculum + Supplemental/ Add-on	Teacher + Parent	1 year	Combined small/large groups	Yes	55
Whittaker et al. (2020)	Kindergarten	Math + Other	N = 720/651	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1–2 years	Combined small/large groups	Yes	25

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TABLE 1 (Continued)

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Elementary school (1st–5th grade; 6–10 years old), *n* = 35										
Blanton et al. (2019)	Elementary school	Math	*N* = 1,495/1343	Environmental at-risk	Curriculum	Teacher	1 year	Classroom	Yes	50
Doabler et al. (2019)	Elementary school	Math	*N* = 49/47	Special educ. needs	Curriculum	Researcher	1–6 months	Small groups	Yes	50
Dowker (2016)	Elementary school	Math	*N* = 88/107	Special educ. needs	Curriculum	Teacher	1 year	Individual	Yes	35
Eble et al. (2021)	Elementary school	Math + Other	*N* = 2,100/2458	Environmental at-risk	Curriculum + Supplemental/ Add-on	Teacher	1–2 years	Classroom	Yes	35
Fabian and Topping (2019)	Elementary school	Math	*N* = 35/39	Unspecified non-at-risk sample	Curriculum	Teacher	1–6 months	Small groups	No	40
Fien et al. (2016)	Elementary school	Math	*N* = 125/125	Special educ. needs	Curriculum + Prof. Dev.	Researcher	1–6 months	Combined small/large groups	Yes	55
Flynn et al. (2012)	Elementary school	Math + Other	*N* = 42/35	Environmental at-risk	Supplemental/Add-on	Parent	1 year	Individual	Yes	40
Fuchs et al. (2010)	Elementary school	Math	*N* = 270/–	Unspecified non-at-risk sample	Curriculum	Researcher	1–6 months	Combined small/large groups	Yes	45
Fuchs et al. (2015)	Elementary school	Math	*N* = 121/84	Low math skills	Curriculum + Supplemental/ Add-on	Teacher	1–6 months	Classroom	Yes	55
Fuchs et al. (2016)	Elementary school	Math	*N* = 147/71	Low math skills	Curriculum + Supplemental/ Add-on	Tutor	1–6 months	Small groups	Yes	45
Fuchs et al. (2021)	Elementary school	Math	*N* = 55/29	Low math skills	Curriculum + Supplemental/ Add-on	Tutor	1–6 months	Small groups	Yes	55
Gersten et al. (2015)	Elementary school	Math	*N* = 615/379	Special educ. needs	Curriculum	Tutor	1 year	Small groups	Yes	55
Greene et al. (2018)	Elementary school	Math	*N* = 15/14	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	Tutor	1–6 months	Small groups	Yes	50

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TABLE 1 (Continued)

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Have et al. (2018)	Elementary school	Math + Other	$N=294/211$	Unspecified non-at-risk sample	Supplemental/Add-on	Teacher	1 year	Classroom	Yes	45
Hickey and Flynn (2019)	Elementary school	Math + Other	$N=34/36$	Environmental at-risk	Curriculum + Supplemental/Add-on	Tutor	1 year	Individual	Yes	40
Jayanthi et al. (2021)	Elementary school	Math	$N=102/103$	Low math skills	Curriculum + Supplemental/Add-on	Researcher	1–6 months	Small groups	Yes	45
Jitendra et al. (2013)	Elementary school	Math	$N=53/56$	Low math skills	Curriculum + Supplemental/Add-on	Tutor	1 year	Small groups	Yes	50
Lakshminarayana et al. (2013)	Elementary school	Math + Other	$N=2,364/2,014$	Unspecified non-at-risk sample	Curriculum + Supplemental/Add-on	Researcher	1–2 years	Classroom	Yes	35
Lee and Choi (2020)	Elementary school	Math	$N=30/31$	Unspecified non-at-risk sample	Curriculum + Supplemental/Add-on	Researcher	1–6 months	Classroom	Yes	45
McTiernan et al. (2016)	Elementary school	Math	$N=14/14$	Low math skills	Curriculum	Other	1 year	Small groups	Yes	50
Nelson et al. (2013)	Elementary school	Math	$N=60/30$	Unspecified non-at-risk sample	Curriculum + Supplemental/Add-on	Researcher	<1 month	Individual	Yes	35
Nelson-Walker et al. (2013)	Elementary school	Math	$N=125/125$	Unspecified non-at-risk sample	Curriculum	Researcher	1–6 months	Individual	Yes	40
Piper et al. (2016)	Elementary school	Math + Other	$N=3143/1028$	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1–2 years	Classroom	Yes	25
Piper et al. (2018)	Elementary school	Math + Other	$N=4,566//$	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1–6 months	Classroom	Yes	50
Pitchford (2015)	Elementary school	Math	$N=113/197$	Unspecified non-at-risk sample	Supplemental/Add-on	Teacher	1–6 months	Classroom	Yes	30
Powell et al. (2022)	Elementary school	Math	$N=139/90$	Low math skills	Curriculum	Teacher	1–6 months	Classroom	Yes	40
Rutherford et al. (2014)	Elementary school	Math	$N=6837/6966$	Special educ. needs	Curriculum + Supplemental/Add-on	Teacher	1–2 years	Classroom	No	45
Sarama et al. (2012)	Elementary school	Math	$N=515/235$	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	>2 years	Individual	Yes	45

(Continued)

TABLE 1 (Continued)

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Swanson (2016)	Elementary school	Math	N = 162/34	Low math skills	Curriculum	Tutor	1–6 months	Small groups	Yes	40
Topping et al. (2011)	Elementary school	Math	N = 4031/85	Unspecified non-at-risk sample	Supplemental/Add-on	Tutor	1–6 months	Individual	No	40
Van den Berg et al. (2019)	Elementary school	Math	N = 170/153	Unspecified non-at-risk sample	Supplemental/Add-on	Teacher	1–6 months	Classroom	No	40
Van Der Heyden et al. (2012)	Elementary school	Math	N = 212/162	Environmental at-risk	Curriculum + Supplemental/ Add-on	Teacher	1–6 months	Small groups	Yes	40
Van der Scheer and Visscher (2018)	Elementary school	Math + Other	N = 269/404	Environmental at-risk	Prof. development	Teacher	1 year	No Info	No	45
Wood et al. (2020)	Elementary school	Math	N = 205/249	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	Teacher	1–6 months	Small groups	No	60
Xin et al. (2017)	Elementary school	Math	N = 17/–	Low math skills	Supplemental/Add-on	Researcher	1–6 months	Individual	Yes	40
Middle school (6–8th grade; 11–13 years old), *n* = 11										
Jitendra et al. (2015)	Middle school	Math	N = 943/955	Unspecified non-at-risk sample	Curriculum + Prof. Dev.	Teacher	1–6 months	Classroom	Yes	50
Jitendra et al. (2017)	Middle school	Math	N = 399/407	Low math skills	Curriculum + Prof. Dev.	Teacher	1–6 months	No Info	Yes	55
Jones et al. (2020)	Middle school	Math + Other	N = 64/31	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	No Info	1–6 months	Individual	Yes	55
Knatauskaitė et al. (2021)	Middle school	Math + Other	N = 89/46	Unspecified non-at-risk sample	Supplemental/Add-on	Teacher	1–6 months	Small groups	Yes	40
Lubans et al. (2018)	Middle school	Math	N = 728/693	Environmental at-risk	Prof. development	Teacher	1 year	No Info	Yes	55
Mensch et al. (2021)	Middle school	Math + Other	N = 799/379	Unspecified non-at-risk sample	Curriculum + Supplemental/ Add-on	Tutor	1–6 months	Small groups	Yes	35
Montague et al. (2014)	Middle school	Math	N = 644/415	Special educ. needs	Curriculum + Prof. Dev.	Teacher	1 years	Combined small/large groups	Yes	50

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TABLE 1 (Continued)

Reference*	Education setting	Intervention target	Sample size treatment/ Control	Sample characteristics	Intervention type	Implementer	Duration	Format	Min effect (main effect on at least one math outcome)	Cochrane risk-of-bias quality score
Núñez et al. (2013)	Middle school	Math + Other	*N* = 47/47	Environmental at-risk	Supplemental/Add-on	Teacher	1 years	Small groups	Yes	30
Pane et al. (2014)	Middle school	Math	*N* = 6143/7302	Unspecified non-at-risk sample	Curriculum	Other	1–2 years	Combined small/large groups	Yes	30
Rohrer et al. (2020)	Middle school	Math	*N* = 398/389	Unspecified non-at-risk sample	Curriculum	Teacher	1–6 months	Classroom	Yes	45
Schüler-Meyer et al. (2019)	Middle school	Math	*N* = 85/43	Environmental at-risk	Supplemental/Add-on	Teacher	<1 month	Small groups	Yes	55
High school (9–12th grade, 13–16 years old), *n* = 2										
Early et al. (2016)	High school	Math + Other	*N* = 1,337/1,378	Environmental at-risk	Curriculum + Supplemental/ Add-on	Teacher	1–2 years	Classroom	Yes	35
Hegedus et al. (2015)	High school	Math	*N* = 298/268	Unspecified non-at-risk sample	Curriculum	Teacher	1–6 months	Combined small/large groups	Yes	40

*The full reference list of the included studies are provided in the Supplementary material.

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3.1 Interventions across educational settings

Table 1 depicts the distribution of the interventions included in the present review across six educational settings. Almost a half (46%, $n = 35$) of the interventions included in the final sample were conducted in the elementary school (from 1st to 5th grade). Only one math intervention targeted very young children in the daycare, thus revealing a large knowledge gap of potential options for promoting children's rudimentary math skills during the first years of life. Moreover, only two (3%, $n = 2$) interventions were conducted in the high school. A somewhat equal number of interventions were conducted among preschoolers (21%, $n = 16$), kindergarteners (13%, $n = 10$), and middle schoolers (15%, $n = 11$).

3.2 Main intervention targets

As evident from Table 2, a higher percentage (66%, $n = 50$) of the interventions targeted children's math skills exclusively compared to interventions targeting both math and other (academic) skills (34%, $n = 25$). The majority of the interventions exclusively targeting math were conducted in the elementary school ($n = 27$), whereas the interventions targeting both math and other skills were more evenly distributed across the other educational settings.

3.3 Sample sizes

The sample sizes per treatment and control groups per math interventions are depicted in Table 1. The total sample size (treatment and control) was $N = 1,116$ in the interventions conducted in the daycare. The mean total sample size in the interventions conducted in the preschool was $M = 837$ ($SD = 1,142$, range $N = 22–4,048$), $M = 582$ ($SD = 493$, range $N = 68–1,373$) in the kindergarten, $M = 1,272$ ($SD = 2,689$, range $N = 28–13,803$) in the elementary school, $M = 1,913$, ($SD = 3,872$, range $N = 94–13,445$) in the middle school, and $M = 1,640$, ($SD = 1,519$, range $N = 566–2,715$) in the high school. Thus, the largest sample sizes were found in the interventions conducted in the middle and high school. However, the sample sizes per treatment group ($F[5, 67] = 0.307$, $p = 0.907$) or per control group ($F[5, 63] = 0.467$, $p = 0.800$) did not vary significantly from each across the educational settings.

3.4 Sample characteristics

Table 3 depicts the distribution of math interventions across sample characteristics, demonstrating that over a half (57%, $n = 43$) of the interventions were targeted at children having environmental risk factors and/or learning difficulties in general, or in math in particular. Moreover, only $n = 2$ studies intervened on children with or at-risk for math difficulties before entering the elementary school, whereas a clear majority of the interventions targeting children with math difficulties were conducted in the elementary school ($n = 10$).

3.5 Intervention types

Table 4 depicts the distribution of math interventions across educational settings by the type of the interventions. Only $n = 3$ (4%) interventions focused exclusively on professional development or coaching of the teachers, whereas most of the interventions included curriculum-based elements in their intervention programs. The purely curriculum-based as well as the combined curriculum and supplemental time-based intervention types were particularly often used in the elementary school. The combination of curriculum and professional development intervention type was most frequently used in the interventions conducted in the preschool.

3.6 Who implemented the intervention?

Table 5 provides an overview of the frequencies of by whom the math interventions were conducted. A half (52%, $n = 39$) of the interventions were implemented by teachers across the educational settings while one fifth of the interventions (20%, $n = 15$) were implemented by researchers. Only $n = 2$ of the studies were conducted solely by parents, and $n = 4$ of the studies were conducted by both teachers and parents across the educational settings, thus revealing a large potential of using parents as interveners of their children's math skills. No studies in the daycare, or in the middle or high school involved parents in the interventions.

TABLE 2 The frequency and percentage of the interventions targeting children's math skills across educational settings.

The main target of the intervention	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
Improve math	0	8	7	27	7	1	**n = 50**	**66%**
Improve math and other (academic) skill	1	8	3	8	4	1	**n = 25**	**34%**
Total *N*	*n* = 1	*n* = 16	*n* = 10	*n* = 35	*n* = 11	*n* = 2	**n = 75**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

TABLE 3 The frequency and percentage of sample characteristics across educational settings.

Sample characteristics	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 Unspecified non-at-risk sample	1	5	4	15	6	1	***n* = 32**	**43%**
2 Environmental at-risk sample (e.g., low SES)	0	10	5	6	3	1	***n* = 25**	**33%**
3 Special educational needs	0	0	0	4	1	0	***n* = 5**	**7%**
4 Low initial math skills or at risk for math difficulties	0	1	1	10	1	0	***n* = 13**	**17%**
Total *N*	*n* = 1	*n* = 16	*n* = 10	*n* = 35	*n* = 11	*n* = 2	***n* = 75**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

TABLE 4 The frequency and percentage of intervention types across educational settings.

Intervention types	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 Professional development/ coaching	0	1	0	1	1	0	***n* = 3**	**4%**
2 Curriculum-based	0	3	4	10	2	1	***n* = 20**	**27%**
3 Supplemental time interventions/"add-ons"	0	4	1	6	3	0	***n* = 14**	**19%**
4 Combination of curriculum and supplemental time based	0	2	3	14	2	0	***n* = 21**	**28%**
5 Combination of curriculum and professional development/ coaching	1	6	2	4	3	1	***n* = 17**	**23%**
Total *N*	*n* = 1	*n* = 16	*n* = 10	*n* = 35	*n* = 11	*n* = 2	***n* = 75**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

3.7 Duration

As depicted in Table 6, a half (55%, $n = 41$) of the interventions lasted for one semester (typically between 1 and 6 months) and one fourth of the interventions (23%, $n = 17$) lasted for 1 year across the educational settings whereas a very few studies lasted for less than a month or over 2 years.

3.8 Format

Table 7 depicts the frequencies of different formats used in the interventions across the educational settings. An approximately equal number of interventions had the children to engage in the intervention related activities either individually, in classroom, in small groups or pairs, or in a combination of different formats across the educational settings.

TABLE 5 The frequency and percentage of interventions by implementer across educational settings.

Who implemented the intervention?	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 Teacher	1	10	2	16	8	2	**$n = 39$**	**52%**
2 Parent	0	1	0	1	0	0	**$n = 2$**	**3%**
3 Tutor	0	1	0	8	1	0	**$n = 10$**	**13%**
4 Both teacher and parent	0	2	2	0	0	0	**$n = 4$**	**5%**
5 Researcher	0	1	5	9	0	0	**$n = 15$**	**20%**
6 Other (e.g., government, principal)	0	0	1	1	1	0	**$n = 3$**	**4%**
7 No information	0	1	0	0	1	0	**$n = 2$**	**3%**
Total *N*	$n = 1$	$n = 16$	$n = 10$	$n = 35$	$n = 11$	$n = 2$	**$n = 75$**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

TABLE 6 The frequency and percentage of duration of interventions across educational settings.

Duration of the intervention	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9th–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 Less than a month	0	2	0	1	1	0	**$n = 4$**	**5%**
2 1–6 months/1 semester	1	6	7	20	6	1	**$n = 41$**	**55%**
3 1 year	0	4	2	9	3	0	**$n = 17$**	**23%**
4 1–2 years	0	4	1	4	1	1	**$n = 11$**	**15%**
5 Over 2 years	0	0	0	1	0	0	**$n = 1$**	**1%**
Total *N*	$n = 1$	$n = 16$	$n = 10$	$n = 35$	$n = 11$	$n = 2$	**$n = 75$**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

3.9 Math outcome measures

Table 8 depicts the different types of math outcomes measured across the math interventions. As each intervention could have up to 10 math related outcomes, the total number of outcomes at each education setting is higher than the total number of studies at each education setting. The most frequently used math outcome measure (70% of all the outcome measures) was a composite score of math achievement or skills. A measure of number sense and arithmetic (i.e., addition, subtraction, multiplication, and division) made up of 18% of all the outcome measure types used in the interventions across education settings. More specific math skills, such as algebra, or fraction understanding, were less frequently measured across the education settings, and they were mainly used as outcome measures in the interventions conducted in the elementary, middle, or high school.

3.10 Evidence of intervention effectiveness

A total of $n = 68$ (91%) of the $n = 75$ math interventions showed a main effect on at least one of the measured math outcomes (see Table 1), thus revealing a large potential of the existing math interventions in promoting children's math skills effectively across educational settings. Six ($n = 6$) of the seven ($n = 7$) math interventions which did not show an effect on any of the measured math outcomes were conducted in the elementary school, whereas one of them was executed in the preschool.

TABLE 7 The frequency and percentage of intervention formats across educational settings.

Format of the intervention	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 Individually	0	3	2	8	1	0	***n*** **= 14**	**19%**
2 In classroom	0	2	0	12	2	1	***n*** **= 17**	**23%**
3 In small groups or in pairs	0	7	3	12	4	0	***n*** **= 26**	**35%**
4 Combination of individual, classroom and/or small groups	1	3	5	2	2	1	***n*** **= 14**	**19%**
5 No information	0	1	0	1	2	0	***n*** **= 4**	**5%**
Total *N*	*n* = 1	*n* = 16	*n* = 10	*n* = 35	*n* = 11	*n* = 2	***n*** **= 75**	**100%**
Total in %	1%	21%	13%	46%	15%	3%	**100%**	

3.11 Quality assessment

The mean score of Cochrane risk-of-bias across the $n = 75$ interventions was $M = 44.66$ ($SD = 8.48$; min = 25; max = 60; see the individual scores per interventions in Table 1). The mean Cochrane risk-of-bias score in the daycare was $M = 40.00$ ($SD = 40.00$), in the preschool $M = 44.37$ ($SD = 7.93$), in the kindergarten $M = 49.00$ ($SD = 10.49$), in the elementary school $M = 43.86$ ($SD = 7.68$), in the middle school $M = 45.45$ ($SD = 10.11$), and in the high school $M = 37.50$ ($SD = 3.53$). There was no statistically significant differences in the Cochrane risk-of-bias scores in the studies conducted across the educational settings, $F(5, 69) = 0.953$, $p = 0.453$. Since the mean score of Cochrane risk-of-bias score was $M = 40.00$ or above in the interventions conducted in all of the educational settings except for high school, the interventions in the final sample were generally rated as having a somewhat low risk of bias.

4 Discussion

The first and second aims of the present systematic review were to identify and to describe the features of math interventions following rigorous randomized controlled design and specifically targeting children's math skills across the broad range of educational settings, from ECE to high school, and across at-risk and non-at-risk sample types. The third aim was to discuss the main findings with focus on the gaps revealed through the systematic review in terms of *where* and *what* types of math interventions are still needed in order to gather more knowledge on how to provide all children, across educational settings and sample types, explicit opportunities for learning math from early on.

4.1 Identification of math interventions across educational settings

The present systematic review exposed a particularly low number of math interventions in the ECE programs in general, and in the very early ECE programs (infant-toddler classes) in particular, which may not be surprising given the fact that most children enter formal schooling first when entering the elementary school. Although almost all countries have ECE programs, they are not compulsory across the world (OECD, 2022), which is why the execution of math interventions may not be possible in many countries until children enter the elementary school. This may partly explain the overweight of math interventions in the elementary school settings identified in the present review, as well as in the previous review literature.

Nevertheless, an increasing number of math interventions have been conducted in either preschool or kindergarten during the past 10 years, suggesting a recent upsurge in interest in promoting children's cognitive skills in the ECE programs. For instance, successful ECE math interventions were identified in the present systemic review, such as the *We Learn Together* intervention (Bleses et al., 2021) targeting toddlers in the Danish daycare setting and the *Building Blocks* intervention (Clements and Sarama, 2008; Clements et al., 2011) targeting 3—5-year-old preschoolers. Moreover, the meta-analysis of math intervention effectiveness in the ECE settings (preschool and kindergarten) by Wang et al. (2016) showed moderate to large effects ($d = 0.62$) on children's math skills. Thus, the execution of math interventions from early on may not only have high potential of leveraging children's math skills here and now but may also benefit children in the long-term.

4.2 Main features of the identified math interventions across educational settings

More than a half of the math interventions identified in the present systematic review involved children at-risk, either due to environmental factors and/or due to learning difficulties (in math). Thus, the likely reason why the clear majority of the previous review literature has primarily focused on the so-called Tier 2 or 3 math interventions (e.g., Jitendra et al., 2018; Lein et al., 2020; Schumacher et al., 2020; Dietrichson et al., 2021; Jitendra et al., 2021; Myers et al., 2022) may be a reflection of the actual number of existing interventions specifically targeting these

TABLE 8 The frequency and percentage of math outcomes across educational settings.

Math outcomes	Daycare	Preschool	Kindergarten	Elementary school (1st–5th grade)	Middle school (6–8th grade)	High school (9–12th grade)	Total *N*	Total in %
	0–2 years old	3–5 years old	5–6 years old	6–10 years old	11–13 years old	13–16 years old		
1 School math grade	0	0	0	0	4	0	***n* = 4**	**2%**
2 Composite score of math achievement/ skills (e.g., Woodcock Johnson, TEMA, TEDI-MATH, and REMA)	0	27	31	85	10	1	***n* = 154**	**70%**
3 Number sense and arithmetic (addition, subtraction, multiplication, and division)	1	7	8	23	1	0	***n* = 40**	**18%**
4 Math language	1	0	0	0	0	0	***n* = 1**	**0%**
5 (Pre-)algebra	0	0	0	0	0	3	***n* = 3**	**1.5%**
6 Fraction understanding and rational numbers	0	0	0	8	5	0	***n* = 13**	**6%**
7 Calculation	0	0	0	3	0	0	***n* = 3**	**1.5%**
8 Geometry, shapes, and measurement	0	1	0	0	1	0	***n* = 2**	**1%**
Total	*n* = 2	*n* = 35	*n* = 39	*n* = 119	*n* = 21	*n* = 4	***n* = 220**	**100%**

sample types, rather than the specific focus of the reviews. Curiously, most of the math interventions identified in the present review targeting students having math and/or learning difficulties were conducted in the elementary school. However, as early skills lay the foundation for the acquisition of later skills, the introduction of math interventions first when entering formal schooling may be suboptimal as building more complex cognitive skills on a weak foundation is more difficult than providing the fundamental building stones for children's learning from the beginning (Shonkoff et al., 2016). Furthermore, despite the fact that previous meta-analytic studies have found overall positive effects of math interventions on children experiencing difficulties with math (e.g., Stevens et al., 2018; Jitendra et al., 2021; Myers et al., 2022), these children are still likely to perform worse than their peers and are prone to exhibit a slower growth in early numeracy, counting, computation, rational numbers, and general math over time (Geary, 2011; Nelson and Powell, 2018).

The majority of the math interventions identified in the present review made use of curriculum-based programs either alone or in combination with supplemental time elements or along with professional development. Surprisingly, the meta-analysis by Williams et al. (2022) found that supplemental time interventions ($g = 0.53$) had larger average effects on children's math skills than curriculum-based interventions ($g = 0.34$) or interventions providing professional development ($g = 0.27$). However, their meta-analysis only operated with these three categorizations, and they did not consider if an intervention incorporated professional development or supplemental elements along with a specific curriculum. Simply providing professional development to the teachers may not benefit children's learning adequately when testing short-term intervention effects on children's math skills. Nevertheless, engaging the teachers and other school personal in professional development may have positive long-term effects on children's math skills. Ultimately, combining curriculum-based activities along with professional development may prove most effective in facilitating math skills in *all* children—and not only those children participating in the specific intervention—in the short and in the long run.

Somewhat surprisingly, only a half of all the math interventions across the educational settings in the present review were conducted by the teachers although almost all interventions were carried out in the educational settings. While some meta-analyses have detected larger intervention effects if the implementer was a researcher ($g=0.71$) compared to a school personnel ($g=0.28$, Lein et al., 2020), the large meta-analysis by Williams et al. (2022) involving several educational settings did not find differential effects between teacher- vs. interventionist-delivered math interventions ($gs=0.37$ and 0.39, respectively). Furthermore, meta-analyses on Tier 2 math interventions targeting students with math difficulties found that interventions were feasibly implemented by both researchers and teachers and that the intervention effects did not differ depending on the implementer (Jitendra et al., 2018, 2021). Teacher and interventionist-delivered programs, however, appeared to be far more effective than computer-delivered math interventions ($g=0.12$, in Williams et al., 2022), thus suggesting that children profit from real-life instructions in terms of math related outcomes.

Only two of the math interventions identified in the present review utilized parents as interveners (Flynn et al., 2012; Griffith et al., 2019), and only four studies involved both parents and teachers (Fantuzzo et al., 2011; O'Connor et al., 2014; Thomas et al., 2018; Schenke et al., 2020). The lack of math interventions conducted in the home environment may reflect the overall lack of literature on the home *numeracy* environment as compared to the home *literacy* environment (Elliott and Bachman, 2018). However, as many adults still struggle with math or even suffer from math anxiety (Geary, 2011), utilizing the parents in math interventions may not be straightforward. In fact, parents' anxiety has been shown to have a negative impact on their children's math achievement, especially when the parent suffering from math anxiety is involved in helping the child with math related tasks (Maloney et al., 2015). Nevertheless, considering the growing evidence of math numeracy environment predicting children's math outcomes (Niklas and Schneider, 2013; Skwarchuk et al., 2014; Hart et al., 2016), involving both parents in the home environment and teachers in the formal education settings may create a stronger coherence between children's learning environments (Skwarchuk et al., 2014).

Finally, the $n=75$ interventions identified across the educational settings in the present systematic review were generally of high quality according to the Cochrane-risk-of-bias score, and the mean sample sizes were generally large across the educational settings, even in the interventions conducted in the ECE settings, although the ECE programs are not compulsory across the globe (OECD, 2022). However, as the analytic approach of the present review was not meta-analytic, we were not able to evaluate the overall effectiveness of the interventions, or the long-term effects on children's math achievement. Nevertheless, as almost all interventions identified in the present review showed a main effect in at least one of the measured math related outcomes, this finding suggests that the interventions include features which may have the potential of elevating children's math skills at least to some extent. This knowledge may be useful for future, more fine-grained meta-analytic studies, examining for whom, in which contexts, and in which ways, math interventions are effective for 0—16-year-old children across the educational settings. Based on the main features of the math interventions identified in the present systematic review, we may expect to find higher effects on children's math skills for interventions conducted in the ECE settings, utilizing the teachers, and involving math-related activities following specifically designed curriculum and supplied with additional professional development.

4.3 Main knowledge gaps in the math intervention literature

The present systematic review revealed four main gaps in the math intervention literature in terms of what type of knowledge is still needed to optimize *all* children's opportunities for learning math across the educational settings from early on.

First, more randomized controlled math interventions are needed in the ECE settings (i.e., infant-toddler classrooms and preschool programs) in order to investigate their long-term effects on children's math skills as well as in relation to their potential of being implemented as a part of the universal ECE programs. For instance, as only one math intervention identified in the present systematic review was conducted in the infant-toddler class (Bleses et al., 2021), and no previous reviews have involved this early educational setting, the question rises whether the positive intervention effects optioned in this particular study can be replicated and maintained over time. Due to the evidence pointing at the importance of introducing children to basic mathematic language and concepts from early on, one could expect universal early ECE programs to benefit all children when entering formal schooling, as the teachers may consequently be able to elevate the overall level of teaching in the class, rather than attempting to adjust the teaching at the lowest level of performance (Duncan et al., 2022). As children's early math skills are positively related to their language and reading skills (Duncan et al., 2007; Peng et al., 2020), additional benefits for children's academic achievement may be attained through early math interventions. However, the existing math interventions in the ECE settings, were not able to illuminate whether and how the positive effects on children's math skills would be likely to sustain over time. Moreover, it is unclear whether the existing math interventions in the formal school settings (i.e., elementary, middle, and high school) were building on children's existing knowledge on math acquired at the previous educational settings and whether the positive effects on math skills would sustain into adulthood. Nevertheless, growing evidence suggests that mandatory introduction to mathematical concepts and operations before children enter formal schooling may be a key in providing children the necessary tools for life-long learning of math and overall academic success (Clements and Sarama, 2011; Siegler, 2016).

Second, more knowledge is needed in terms of how math interventions can benefit children in general—and not only children needing additional support in math—as all children profit from explicit learning opportunities of math. As the majority of the review literature on math interventions synthetize results from interventions targeting at-risk students, it is still unclear to what extent the factors contributing to the intervention effects for at-risk students can be applied to non-at-risk students. After all, there are also differences between Tier 2 and Tier 3 interventions in terms of the intensity, duration, grouping, and instructions, although both intervention types target at-risk students (Harlacher, 2023). As lower performing students are likely to profit from positive peer effects when they are included in classrooms with their higher achieving peers (Dietrichson et al., 2021; Duncan et al., 2022), future studies could investigate whether the intervention will have larger learning gains in math for children from at-risk backgrounds if they are included in the intervention along with their non-at-risk peers. Consequently, such math interventions may have the potential of reducing the achievement gaps between students leading to less inequality in terms of later success in education, STEM-related career options, and well-being for all children.

Third, although a large share of the identified math interventions in the present systematic review made use of curriculum-based programs across the different educational settings, less is still known of how the specific math curriculum-based elements may have the potential of being implemented as a part of normal teaching in the universal educational programs. Additionally, more knowledge is needed in how future math interventions can make use of the teachers, who are most knowledgeable of their individual students' skill level and are therefore capable of adjusting the curriculum-based elements in their teaching accordingly. A large proportion of the math interventions identified in the present systematic review made use of researchers as implementers, who may be effective in delivering short-term intervention effects but may prevent the students from benefiting from additional learning after the termination of the study. Ideally, by using the teachers as the implementers of the intervention, teachers would become more qualified in facilitating additional learning after the termination of the intervention study, especially if supported with professional development in delivering curriculum-specific instructions.

Finally, more knowledge is needed to what extent and in which ways parents could be involved in future math intervention studies and how the overall home numeracy environment could be supported (Skwarchuk et al., 2014). In fact, there is growing evidence showing how especially formal (e.g., counting and number recognition) and to some extent informal learning activities (e.g., playing board games) at home can promote children's early numeracy skills (Elliott and Bachman, 2018). However, involving the parents in math-related activities and in math homework may have to account for parents' own math-related attitudes and challenges as a part of the intervention, as outlined above. Nevertheless, by providing children various opportunities to play, explore, and experiment with figures, shapes, and numbers across various learning environments, children's curiosity toward mathematics may not only be awakened but also maintained as children move on to later grades (Hannula-Sormunen et al., 2023).

Overall, the present systematic review of math interventions conducted across educational settings has brought to attention the fact that there are still disproportionally large gaps in the math intervention literature in the infant-toddler and preschool settings as well as in the math interventions involving both at-risk and non-at-risk students, which previous review literature have not shed light on before due to their narrow focus on specific target- and/or age groups.

4.4 Limitations

The present systematic review has a range of limitations. First, it was beyond the scope of this review to evaluate the effectiveness of the included math interventions in terms of the specific math related outcomes across interventions and educational settings. Moreover, we were not able to disentangle whether and how the positive outcomes in the "effective" interventions were moderated or mediated by other factors. However, this is done elsewhere in other meta-analytic reviews (Williams et al., 2022). Another limitation is that the present review was only based on short-term effects. There is evidence suggesting that educational intervention effects—especially effects attained in the ECE settings—are likely to fade-out over time although the mechanisms and reasons for fade-out effects are still less understood (Bailey et al., 2020). Thus, follow-up studies are needed, and future studies should aim at addressing how to gain sustainable positive effects in children's math skills over time. Finally, although the strength of the present systematic review was the inclusion of math interventions conducted across a broad range of education settings from infant-toddler classrooms to high school, the large inclusion range also limits a detailed description of the characteristics of the intervention at each education setting.

4.5 Conclusion

The foundation for children's learning and understanding of mathematical concepts and operations is laid from early on, and therefore, all children—both at-risk and non-at-risk—ought to be introduced to numbers and basic mathematical concepts already in the early educational settings. By providing teachers and parents the tools for engaging the children in meaningful and enjoyable math-related activities in school and at home, a synergy is established between children's learning environments and children's curiosity for long-term learning of math may be strengthened. Ultimately, children with better early math skills are equipped to perform better in STEM-related subjects later, but also have higher chances for academic and occupational success in life in general.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

RPS, MMW, DB, PK, MV, and HSN contributed to the development of the research question, to the design of the scope of the review, and the overall design. RPS and MMW were responsible for all the steps in the systematic literature search and screening process, and supervised the student assistants in the abstract- and full-text screening. RPS developed the coding scheme and coded the data in collaboration with MMW. MMW contributed to the analysis and reporting of the data. RPS wrote the first draft of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2023.1229849/full#supplementary-material

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