Interventions to improve mathematical achievement in primary school-aged children


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Interventions to improve mathematical achievement in primary school-aged children

A Systematic Review
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Interventions to improve mathematical achievement in primary school-aged children A Systematic Review
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A Systematic Review

Executive Summary
Mathematical achievement is important for children’s future educational success, employment opportunities and health outcomes. However, it is recognised that there is a substantial underachievement in this subject (e.g. DE, 2015). There is a growing body of literature that assesses the impact of interventions on mathematical achievement (DFE, 2012).

This review of published studies rigorously investigated the outcomes of classroom-based mathematical interventions that were targeted at primary school-aged children. The review assessed whether the interventions had an effect on mathematical achievement (as measured by variety of outcome measures) or related attitudinal or affective outcomes. The review assessed whether the interventions were targeted at primary school-aged children. Forty-five randomized control trials were included along with thirty-five quasi-experimental studies. The studies were published between 2000 and 2017. These studies were totally recorded on the internet prior to beginning the review process so that readers can be assured that the work is rigorous.

Some definitions
What do we mean by interventions?
In this review the term ‘intervention’ is defined as a routine materials that would be available in most Western-classroom, such as through song or story books.

2. What are the most effective classroom-based interventions for improving mathematical learning in primary school-aged children?
...This review highlights the necessity of criteria that may be applied to identify a child as having mathematical disability.

Conclusions
The studies identified in this review suggested that there are a number of approaches that have potential to promote mathematical learning in mainstream primary classrooms; 1. Focusing on key topic areas in mathematics such as conceptual understanding, magnitudes, and basic number skills. 2. Ensuring that children have a wide bank of strategies to draw upon. 3. Ensuring that children have a fluent grasp of mathematical facts. 4. Providing effective and timely feedback.

Recommendations
Policy makers should consider the following recommendations: 1. The development of guidance on interventions should be made with caution on the majority of the criteria that we identified was of low quality.
2. Support teachers through training or evidence-based education so that they can evaluate studies which rigorous evidence of effectiveness does or does not exist.
3. Develop a Core Outcome Set (an agreed set of outcome measures to aid comparison across studies.)

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The need for the review

Mathematics skills are increasingly important for everyday life because many careers require some form of mathematical understanding and decision making (Kings, 2013). Yet, low levels of mathematical achievement in primary school-aged children have been reported across the globe (e.g., a Chance Trust, 2009; Skills for life, 2012). Research has largely focused on interventions for those with a suspected or diagnosed mathematical learning difficulty. However, there are no consistent standards by which to judge the effectiveness of these interventions, and there is a growing concern that the training of primary school teachers is insufficiently geared towards greater understanding of how to increase mathematical achievement in primary schools (Aikenhead et al., 2015). Some research indicates that this concern is not misplaced. Learning mathematics in the 11-year-olds leave primary school without reaching the mathematical level expected. Learning mathematics in the UK population meet the diagnostic criteria for dyscalculia (Karagiannakis, Baccaglini-Frank & Papadatos, 2015). Specifically, Gross (2007) reported that 21% of children in Northern Ireland placed this rate in primary school. Additionally, it is estimated that 15-17 million adults have poor numeracy skills (Every Child Matters, 2005). The need for the review

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The aim of evidence-based education is to provide education professionals with evidence from research about which theories of learning and teaching have received support from research studies. Teachers can then use their expertise and experience to determine how the theory might apply in their classroom.

Different sources of evidence

There may be a number of different types of research methods used to gather evidence. In this chapter, we focus on the ways in which evidence-based education, including formal or less formal trials of interventions, has served to inform theories of learning and teaching. Evidence-based education research studies investigate learning and teaching to explore and test ideas about how children learn so teachers can make informed decisions about what might work well in their own context. The evidence can then be used to help children learn as effectively as possible. Recent research has been dedicated to developing effective interventions to improve mathematical learning in primary school (e.g., DeLano-Segui et al., 2015). Recent reports have called for an increase in systematic and rigorous investigations of educational interventions to provide an evidence-base for educational reform (Aikenhead et al., 2015). This type of approach encourages teachers to consider how effective practice can be guided by the best available evidence.

Evidence-based education: What is it?

Many commentators have called for educational policy and practice to be guided by the best available evidence. This is known as evidence-based education. The aim of evidence-based education is to provide education professionals with evidence from research about which theories of learning and teaching have received support from research studies. Teachers can then use their expertise and experience to determine how the theory might apply in their classroom.

Different sources of evidence

There are many different types of research methods used to gather evidence. In this chapter, we focus on the ways in which evidence-based education, including formal or less formal trials of interventions, has served to inform theories of learning and teaching. Evidence-based education research studies investigate learning and teaching to explore and test ideas about how children learn so teachers can make informed decisions about what might work well in their own context.

Evidence-based education is not, however, straightforward (König, Saw & Siddiqui, 2017). Some educationalists may be concerned that this approach diminishes the expertise of teachers and the art of teaching or that the limitations of research studies are not relevant for the classroom. However, this is not the case. Evidence-based education does not generate prescriptive rules (a “recipe book”). Teachers are free to interpret research and explore the new ideas in their own context. Nevertheless, it is important to think about how children learn to teach and how their teaching can be improved. Research studies investigate learning and teaching to explore and test ideas about how children learn so teachers can make informed decisions about what might work well in their own context.

Evidence-based education is also not limited to research studies. It can apply in different contexts. Researchers often use the results of research studies to influence policy and practice rather than just to teach teachers. Researchers can also use the results of research studies to promote specific educational programs or curricula. Some educationalists may be concerned that this approach diminishes the expertise of teachers and the art of teaching or that the limitations of research studies are not relevant for the classroom. However, this is not the case. Evidence-based education does not generate prescriptive rules (a “recipe book”). Teachers are free to interpret research and explore the new ideas in their own context. Nevertheless, it is important to think about how children learn to teach and how their teaching can be improved. Research studies investigate learning and teaching to explore and test ideas about how children learn so teachers can make informed decisions about what might work well in their own context.

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A systematic review begins by posing a question, such as: what effect do classroom-based mathematics interventions have on mathematics achievement for primary school-aged children? In order to answer this question, researchers need to find any study that has tested the effect of a mathematics intervention in primary schools. Researchers then develop and run a comprehensive search strategy that allows them to find as many relevant studies as possible. The search strategy includes a database or databases where the studies were published. Searches should also look for relevant unpublished research, such as documents in the grey literature, which have not been published in academic journals. This helps to avoid possible publication bias and allows for maximum coverage of the literature. Searches should not be limited to studies that are peer reviewed; instead, they should be run on all available databases to ensure that no relevant studies are missed. Searches identified through the search strategy are then collated together and checked against the review’s inclusion criteria. This process aims to identify the scope or topic of the intervention, the setting in which the intervention is delivered, and the nature of study participants, or the way the research was conducted.

Importantly, everything that happens as part of a systematic review, from the search strategy through to the methods of data analysis, is described in detail, and ideally, written up as a review protocol that is published online (for example, through https://www.crd.york.ac.uk/prospero/). This makes the systematic review process as transparent as possible thus avoiding bias.

The aims of this review

By systematically reviewing evidence on the effectiveness of a range of mainstream student-directed classroom-based interventions aimed to allow benchmarking of policy makers across and collaborative research to meet the needs of those motivated on appropriate teaching practices and interventions. The included trials were classroom-based mathematics interventions delivered to individual pupils, such as those applied at the whole-class level and one-to-one support, delivered by trained teaching professionals as well as through other mediums such as peer teaching.

This wide variety of potential interventions to improve mathematical achievement in children, and the need for evidence being communicated to educators about effective strategies to improve learning outcomes. Given that there is little evidence of transfer of training from different general situations, such as working memory training, to mathematical achievement, or in fact some reports of negative impact (e.g. Roberts et al., 2016), interventions with a mathematical content are regarded as a more plausible candidate for successful outcomes.

Therefore, this broad review of interventions aims to examine what types of classroom-based learning for children are the right approach for the rapid development of new interventions. An evidence base is a broad, rather than narrow, review process to identify practices that may be beneficial for a specific group of children. First the studies are collated, and if necessary, written up as a review protocol. The search terms used in the electronic databases are listed in Table 1. These terms are entered into each of the databases above to identify materials that contain specific terms.

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In addition, following best practice (Hemsworth, Wede, & Jemison, 2016), current issues of journals in which relevant articles had been found were hand searched. Reference
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Criteria for inclusion and exclusion from the search

The following criteria were used to assess if a study would be included in the final systematic review.

Types of studies

Included:
- Randomised controlled trials (including cluster-randomised controlled trials)
- Quasi-experimental designs
- Must include comparison control condition (e.g. no intervention, practice-as-usual, waiting list, or active control group)

Excluded:
- Matched subject or group designs
- Cross-over designs
- Single-subject designs
- Conventional designs

Time and language:
- All eligible studies were published from January 2000 to ensure that the materials included were relevant in terms of curriculum context, to the time of literature search conclusion (up to August 2017). Full texts must have been available in English.

Types of participants

Included:
- Participants are children aged 4-11 years’ old
- Attending mainstream primary/elementary-level schools

Excluded:
- Samples selected due to suspected or diagnosed mathematical difficulties (e.g. mathematics achievement below the 25th percentile or less on standardized mathematical tests)
- Samples attending special education establishments
- Samples with other diagnosed learning difficulties or developmental disorders

Types of interventions

Included:
- Interventions (specific deviations from existing practice) aimed at improving mathematics skills (e.g. speeded recall of arithmetic facts, flexible strategy use)
- Interventions carried out in school settings, not laboratory based studies
- Administered individually, within small groups or whole-class based
- Delivery method includes those delivered by teachers, teaching/classroom assistants or other trained professionals
- At least one follow-up at post-test was necessary (within one month)

Excluded:
- Interventions aimed at children screened for or suspected of dyscalculia
- Interventions aimed at parents and requiring parent participation

Types of outcome measures

Primary outcome measures
The primary outcome was mathematics achievement, as measured by:

- Curriculum-based outcome measures (e.g. Key Stage assessments)
- Standardised tests (e.g. Wechsler Individual Achievement Test Numerical Operations or Mathematics Reasoning)
- Cognitive experimental measures of specific mathematics skills (e.g. timed recall of arithmetic facts, flexible strategy use)

Secondary Outcomes
Secondary outcomes included attitudinal or affective measures, e.g. attitude towards mathematics, mathematics anxiety levels, mathematics self-efficacy, confidence in or enjoyment of mathematics. In addition, where available, costs associated with the intervention (e.g. unit costs or costs per student, technology costs) were extracted.

Duration of a follow-up
- Immediate post-test outcomes (up to 30 days post-intervention)
- Longer term follow-up grouped into similar periods (e.g. after 6 months) where available.

Types of settings
Only interventions directed towards students, specifically not curriculum-based changes, in mainstream classrooms were included.

Selection of studies
A research assistant trained in information retrieval and mentored by Cochrane Ireland and the Campbell Collaboration conducted the initial search following the pre-registered search strategy (Table 1). Titles and abstracts were checked independently by two of the review team against the inclusion/exclusion criteria. Full texts of potentially eligible studies were located and again screened independently by two of the author team. Any decision disagreements were resolved through discussion and consensus as a team. Reasons for excluding studies were documented.

Overall, the preliminary search identified 10,042 potential papers. Title and abstract screening followed by full text screening applying inclusion and exclusion criteria removed 9,962 studies, leaving a total of 80 included studies.
Findings of the review

RCTs provide more rigorous evidence for the effectiveness of interventions than quasi-experimental trials (i.e. studies, where participants were not randomly assigned to groups). Quasi-experimental trials can identify promising interventions that may be the basis for future RCT studies. Although these studies do not have as rigorously methodology the information generated by these studies may assist in informing practice. Therefore, we clearly highlight the evidence from studies using these two types of research methodologies in the following summary sections.

Overview of included studies

The search identified 80 papers that met the inclusion criteria for this systematic review, with 45 RCT and 35 quasi-experimental studies (Figure 2). Overall, these studies included data from 14,198 primary school-aged children (mean ± 1808 per study). The context of each paper was assessed on its suitability for quantitatively synthesising the outcome data to compare the impact of each intervention (commonly described as a meta-analysis). The studies focused on a wide variety of Mathematics topics and used in wide range of standardised and outcome experimental outcomes. In fact, 61 studies used at least one author-generated test as an outcome measure. This makes any comparison of data across studies very difficult in intervention intensity was diverse across studies: some papers reported data from one or two sessions to interventions lasting two years (Table 3). Therefore, we concluded that synthesising the outcome data across studies would not be appropriate. For example, it would not be meaningful to quantitatively compare the effect of a single session of instruction or songs activity or songs content, such as group work, physical game format to encourage children's learning about mathematical concepts, specifically geometry (Al-ebous, 2016), number principles (i.e. primes and composite numbers, Ploger & Hecht, 2009) or mathematical concepts more generally (Rutherford et al., 2014; González-Calderón & Madrid, 2003). These studies reported benefits of teaching conceptual understanding of the equals sign using manipulatives, providing feedback, technology for engagement and varying delivery contexts.

Instead, we conducted a narrative synthesis of the included papers. Studies were classified as belonging to one of two larger themes that encompassed the studies that may form the basis for future RCT studies. Although these studies do not have as rigorous methodology the information generated by these studies may assist in informing practice. Therefore, we clearly highlight the evidence from studies using these two types of research methodologies in the following summary sections.

Methods of Instruction. The subthemes within the Topic Areas in Mathematics included conceptual understanding, magnitudes, basic number skills, practice for fluency and strategy use. The subthemes with the Methods of Instruction theme included the use of manipulatives, providing feedback, technology for engagement and varying delivery contexts.

Eighteen papers provided results from studies on the effect of teaching conceptual understanding of the equals sign using manipulatives, providing feedback, technology for engagement and varying delivery contexts. Four studies focused on improving children’s understanding of mathematical equivalence by restructuring the format of certain tasks. These studies reported benefits of teaching conceptual understanding of the equals sign using manipulatives, providing feedback, technology for engagement and varying delivery contexts.

Conversational understanding

Fourteen studies focused on improving children’s conceptual understanding (Table 3). Ten studies were RCTs and four were quasi-experimental trials.

All of these interventions demonstrated a significant increase in performance on outcome measures when compared to a control group. Where clearly specified, age groups included in these studies ranged from 5 to 11 years.

Four of the studies used visualisation methods (i.e. requiring children to use visual diagrams or schemes that were either paper or computer-based, to attempt to support children’s learning about mathematical concepts, specifically geometry (Al-ebous, 2016), number principles (i.e. primes and composite numbers, Ploger & Hecht, 2009) or mathematical concepts more generally (Rutherford et al., 2014; González-Calderón & Madrid, 2003). These studies reported benefits of teaching conceptual understanding of the equals sign using manipulatives, providing feedback, technology for engagement and varying delivery contexts.
Four studies assessed whether training conceptual understanding of numbers improved mathematical processing. Fazio et al. (2015) manipulated subtraction and addition concepts, with mixed findings on a number of outcome measures. In particular, some mixed results were reported in these studies, dependent on age. Furthermore, the number of multiplication problems to be learnt using practice approaches to mental addition: strategic addition or non-strategic addition was varied. However, in general positive results were reported for the intervention across various mathematics problem solving assessments. Cohen et al. (2015) observed that computerised practice increased children's multiplicative reasoning skills. Zutaut, Panhuize and Robitzsch (2015) observed that computerised mathematics games integrated into mathematics lessons improved children’s multiplicative reasoning skills. Zutaut et al. (2015) observed that computerised mathematics games improved children’s number comparison skills. Overall, training improved addition fluency.

Practice for Fluency

A final study investigated the impact of presentation format (paper and pencil versus computerised tasks) on training basic number skills (Mascia et al., 2013). Improvement in numerical knowledge was observed in both experimental groups when compared to a control group, but there was no difference in performance between experimental groups.

Related studies investigating the impact of computerised mathematics games on children’s performance across mathematical problem solving tasks. Van der Ven, Segui, Takashita and Verbeiren (2017) also used adaptive computerised program that presented children with numerous symbolic mathematics problems. Children were encouraged to solve problems with speed in response to feedback. Students who were exposed to the intervention showed increased in efficiency in non-symbolic subtraction, but not in symbolic addition. This study also reported that children who were trained with non-symbolic comparison showed improvements in symbolic mathematics when compared to a control group. Similarly, Khanum et al. (2016) observed that training in non-symbolic comparison showed improvements in symbolic mathematics when compared to controls. However, working memory training did not improve mathematical word problems solving whilst number sense training did not.

Three studies specifically investigated the impact of training conceptual understanding of numbers on a number of outcome measures. Three studies specifically investigated the impact of training conceptual understanding of numbers on a number of outcome measures. Some mixed results were reported in these studies, dependent on age.
The twelve studies assessed the transfer of strategy and the ability to apply effective and efficient strategies. Prior research has suggested that flexible strategy use can improve mathematical achievement. Twelve studies intervened on strategy use (Table 7).

Interventions to improve mathematical achievement in primary school-aged children reflect on the strategy they used. Children in this experimental group displayed significant improvements in the experimental condition compared to the control condition. Three studies focused on problem solving for specific types of mathematical problems. These studies investigated the impact of providing and reflecting on visual cues to support strategy use. Both Desoete (2009) and Onu, Eskay, Mason and Scrivani (2004) focused on improving children's understanding of mathematical problems. Erkfritz-Gay (2009) assessed the impact of providing and reflecting on visual cues to support strategy use. Children in the experimental condition showed a significant improvement in their ability to solve new problems by drawing out their strategy and then reflecting on the strategies that could be applied to problem solving. Children who were encouraged to reflect on these metacognitive processes generally showed greater gains in mathematical word problem solving and reflection on strategy use. Both Desoete (2009) and Onu, Eskay, Mason and Scrivani (2004) focused on improving children's understanding of mathematical problems. Erkfritz-Gay (2009) assessed the impact of providing and reflecting on visual cues to support strategy use. Children in the experimental condition showed a significant improvement in their ability to solve new problems by drawing out their strategy and then reflecting on the strategies that could be applied to problem solving.

Children were assessed by Sulak (2010). This study indicated that children who were provided with structured feedback were more likely to increase their understanding of mathematical problems. Griffin and Jitendra (2008) assessed the impact of schema training. No significant group differences in performance were observed. Children who experienced the intervention that included the capacity for transformation were more likely to increase their understanding of mathematical problems. Children who were encouraged to transform their strategies were reported to have increased performance in comparison to a control group. Pagar (2013) assessed the impact of a digital manipulative intervention that either had elements that could be transformed by students or not. Findings were mixed, with some participants showing differential effects dependent on participant characteristics. The identified studies indicate that feedback may have different effects depending on participant characteristics. Participators (2013) demonstrated that participants with higher performance benefited more from summative feedback than lower performing participants. Fyfe and Lightle-Johnson (2016), noted that only participants with low prior knowledge benefited from either immediate or summative feedback.

Two additional studies used virtual manipulatives to improve mathematical achievement. Acevedo and Stein (2011) and Koepp and Sugie (2013) observed positive effects (Table 8). These studies used virtual manipulatives to support strategy use. Children who were provided with structured feedback were more likely to increase their understanding of mathematical problems. Children who were encouraged to transform their strategies were reported to have increased performance in comparison to a control group. The identified studies indicate that feedback may have different effects depending on participant characteristics. Participators (2013) demonstrated that participants with higher performance benefited more from summative feedback than lower performing participants. Fyfe and Lightle-Johnson (2016), noted that only participants with low prior knowledge benefited from either immediate or summative feedback.

Technology for engagement

Eleven studies used virtual learning environments in order to engage children in mathematical content (Table 10). Children in these studies were slightly older than those involved in other themes (8 to 11 years-old). Findings in these studies were mixed. Five studies assessed the impact of broad context-based learning programmes on student engagement. Keck and Heitkamp (2013) assessed the effectiveness of a web-based problem-solving site that also provided tips on thinking skills. Children who experienced the website significantly outperformed a control group in both problem-solving skills and self-monitoring. Fil and Aksu (2013) assessed the impact of familiar Algebra software compared to traditional instruction. Children who experienced the software significantly outperformed a control group in both problem-solving skills and self-monitoring.
 understands. Embedding mathematical instruction in digital technology has been found to have significant benefits for mathematical achievement (as measured by standardized tests) in comparison to more traditional methods of instruction. Barzilai and Blau (2014) established that children needed to study the content that would be practiced in the game first to benefit from this software incorporated problem based learning, practice and games. Children who experienced the intervention group significantly outperformed those in the control group. Experimental group significantly outperformed those in the control group. Children in the experimental group outperformed children taught in a control group in a comparison to a control group. Children in the experimental group outperformed children taught through digital technology would improve outcomes.

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Interventions to improve mathematical achievement in primary school-aged children

Summary

The narrative summary of the 80 studies clearly displays the wide variety of interventions used to improve mathematical achievement in primary school-aged children. The majority of interventions reported a positive impact of the assessed intervention on at least one of their outcome measures (72% of those that could be coded and were coded out of 80 included studies). Interventions were identified across the globe in Europe, USA, China and India (Figure 3). The interventions varied in sample size, ranging from 16 to 1,808 participants. Interventions also varied in intensity from one-off sessions to multiple sessions over a period of two years.

Even though the report only included studies that used rigorous methods their results may all be great variation in the quality of the studies found. The researchers were required to assess the rigour and quality of the included RCTs with researchers using seven recognised criteria (Cochrane Collaboration's Risk of Bias tool, Higgins & Green, 2011). In order to reduce risk of bias in all studies should be independently assessed by groups using a rigorous and well-documented methodology for each study. This was done by researchers assessing all studies from participants and researchers whilst data collection is ongoing. According to the overall review of group membership can lead to different expectations for individual's performance. This biasing tool reveals. Therefore, risk of bias can also be reduced by ensuring that (3) participants are not aware of the group they are assigned to (4) interventions are matched (5) random assignment (6) participants are not informed of the group they are assigned to (7) researchers assessing outcomes are not aware of group membership of the individuals that they are measuring. High risk of bias due to the following reasons (a) knowledge of group composition (b) knowledge of intervention (c) knowledge of outcome measures. These factors should be provided to ascertain that drop out levels are low (i.e. <20%). (8) finally, an additional factor that can influence bias is that where authors report only outcomes that have been significantly improved by an intervention. Therefore, studies should be pre-registered. This means that (7) authors should carefully and publicly outline their research questions and methods prior to data collection. Readers can therefore check that all pre-registered studies are reported and that authors have not selectively reported outcome measures.

Assessment of rigour and potential for bias in included RCT studies

Evaluating the quality of the included RCTs was that there was not enough information contained within the papers to make an evidenced-based judgment about the potential for bias across a number of factors. Therefore, it was very difficult to make an assessment of the rigour of the included studies. (See Grimes & Schulz, 2001, for further details).

Table 3: Systematic review of included studies

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Sample Size</th>
<th>Duration</th>
<th>Methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single session</td>
<td>16</td>
<td>1 week</td>
<td></td>
</tr>
<tr>
<td>Multiple sessions</td>
<td>1,808</td>
<td>2 years</td>
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</table>

Figures 3 & 4: Geographic spread of included studies

The wide diversity of the identified studies emphasizes a number of issues. First of all, mathematics is a multi-dimensional subject (Dowker, 2009). The wide variety of target subjects for intervention is not surprising. However, as a consequence of this diversity the outcomes of the identified studies need to be interpreted with caution. Thus, the wide diversity of the identified studies underlines the need for group members to provide clear information on the group composition to inform their practice or policy recommendations.

Discussion

Summary of results

Through the systematic review process we identified 45 RCT studies and 35 quasi-experimental studies that met inclusion criteria. It is surprising that so few studies were identified. Practitioners and policy makers therefore have a limited evidence base to inform their practice or policy recommendations.

What are the most effective classroom-based interventions for improving mathematical learning in primary school-aged children who do not meet the criteria for mathematics disability?

At the protocol stage we anticipated that we would be able to use metanlysis to identify the most effective interventions. However, due to the nature of the data available in the identified studies assessing a variety of different types of delivery methods, it was anticipated that we would be able to use meta-analysis to identify the most effective interventions. For example, it would not be meaningful to try to determine whether strategy training for algebra problems is “more or less effective” than physical objects, changes in providing feedback, or movement. Studies also varied widely in their duration and intensity. Overall, the majority of interventions reported to be effective in terms of reducing learning difficulties.

Conclusions

Practitioners and policy makers therefore have a limited evidence base to inform their practice or policy recommendations. It is highly likely that additional trials will investigate interventions that will provide little evidence for practitioners seeking to make decisions about their pedagogical approach in the classroom. However, as a consequence of this diversity the literature on mathematical interventions lacks coherence and may not be seen as relevant to practitioners seeking evidence-based approaches. Knowledge of effective interventions is required to rectify the well-known bias in relation to publishing null results. Therefore, a diverse battery of outcome measures should be used with primary school-aged children who do not meet the criteria for mathematics disability (e.g. equipment, any associated costs).

What are the key characteristics of the most effective interventions for improving mathematical learning in primary-school-aged children who do not meet the criteria for mathematics disability?

As a consequence of this diversity the literature on mathematical interventions lacks coherence and may not be seen as relevant to practitioners seeking evidence-based approaches. Knowledge of effective interventions is required to rectify the well-known bias in relation to publishing null results. Therefore, a diverse battery of outcome measures should be used with primary school-aged children who do not meet the criteria for mathematics disability (e.g. equipment, any associated costs).

Resources for requirement for the studies

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required commercially available books to be used as stimuli for learning. Nine studies required specific classroom software for the intervention (e.g. abacus or playing cards). Twenty-six of the studies assessed the use of commercially available software; these products easily produce these materials.

Interventions to improve mathematical achievement in primary school-aged children

Some important additional findings

The importance of underpinning theory in developing interventions

When we reviewed each study it was clear that many interventions were based on strong psychological or learning theory. However, there were numerous studies that we identified, in particular summarized within the “Technology for Engagement” subsection (Table 10) that lacked theoretical rationale to explain potential mechanisms for change in outcomes. It is important to report that intervention studies can add substantially to pedagogical practice when they test a theoretically grounded intervention can impact on the intervention (e.g. abacus or playing cards). Twenty-six of the studies identified in this area was surprising. This review indicates the necessity for rigorous trials of commercially available interventions, such as software and games, to assist teachers and policy makers’ decision making.

Lack of rigorous studies of commercially available products

The review only identified thirteen studies of commercially available products. These were all either book or software-based interventions. There are numerous commercially available products marketed towards schools, for example those that involve physical objects for teaching mathematical skills. Therefore, the small number of rigorous interventions that were identified in this area was surprising. This review indicates the necessity for rigorous trials of commercially available interventions, such as software and games, to assist teachers and policy makers’ decision making.

Quality of available evidence

As important to the reader was that many of the studies did not contain sufficient evidence to make an intervention decision. The majority of the studies identified within this specific context of the study (see for example, Deans for Import, 2015) indicates the necessity for rigorous trials of commercially available software, these products had associated purchasing costs, but the majority were not specified. Twenty-six of the studies reviewed the use of author-generated or adapted software. Some important additional findings

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Interventions to improve mathematical achievement in primary school-aged children

The current review focused on childhood-related interventions rather than interventions that were implemented at institutional or curriculum levels. The authors focused on these childhood-related interventions because, while it is within a teacher’s control to change their own practice, this is not necessarily the case at the systemic level. Therefore, this review has practical applications for individual educational practitioners. However, there are three published Campbell reviews that focus on the impact of systemic change in schools on mathematical achievement (along with other educational outcomes). Krevels, Harald and Jan (2017) noted that the introduction of “No Excuse” charter schools were associated with greater gains in mathematical achievement than traditional state-funded schools. A small positive impact on mathematics performance was observed through the introduction of school-based interventions making in middle-income countries (CarlHill, Bullock, Schindler, 2016). Changes in teacher recruitment and training in middle-income countries (Carr-Hill, Rolleston, Schendel, 2016). The current review focused on child-directed interventions aimed at improving mathematical achievement for children from pre-school through to secondary school, including those aimed at improving mathematical achievement for children with mathematical learning difficulties. This review was not pre-registered. The authors made the decision to carry out meta-analysis on a wide variety of outcome measures, in contrast to the decision that we made. Fischer et al. (2013) concluded that efficacy of an intervention was linked to the type of intervention and the rigour of the trial. The current review observed that nearly all studies reported positive effects, but the majority of studies had issues with potential of bias. However, findings from these reviews should also be treated with caution due to limitations.

Existing relevant reviews

In addition to this systematic review there are three existing reviews that teachers and policy makers may find useful. However, findings from these reviews should also be treated with caution due to limitations. Fischer, Atwell, Cool, Naehr (2013) conducted a review and synthesised the data (i.e. carried out meta-analysis) from studies to assess the impact of a variety of interventions aimed at improving mathematical achievement for children from preschool through to secondary school, including those with mathematical learning difficulties. This review was not pre-registered. The authors made the decision to carry out meta-analysis on a wide variety of outcome measures, in addition, this review indicates the importance of pre-registration of trials to ensure transparency in the assessment of educational interventions, especially selective outcome reporting. Pre-registration of rigorously designed studies may also increase the probability of null findings being published, thus increasing the evidence base for mathematical interventions.

No replication studies were identified through the systematic review. With increasing recognition of the importance of replication to generate bodies of evidence it is apparent that this area is in need of further research. In addition, only a small proportion of these identified studies specifically report replication. In addition, this review highlights the importance of replication to generate bodies of evidence it is apparent that this area is in need of further research. In addition, only a small proportion of these identified studies specifically report replication. In addition, this review indicates the importance of replication and the rigour of the trial. The current review observed that nearly all studies reported positive effects, but the majority of studies had issues with potential of bias. However, findings from these reviews should also be treated with caution due to limitations.

Conclusions

This review identified a number of studies that assess mathematical interventions. Overall, these studies suggest that changes in teaching practice can improve mathematical achievement. This can be done through a variety of mechanisms, such as changing the method of delivery of content (e.g. computer-based tasks, groupwork), providing better and more structured feedback or by using additional tools in real learning (e.g. abacus, rulers, shapes). In addition, focusing on key skills and concepts (e.g. fluency, strategy use) may lead to an increase in mathematical achievement. However, caution is needed because the methods used in many of these studies allow for some bias in interpretation.

As the studies identified in this review were of varying quality and many are not easily accessible to educational practitioners it is very important that a number of messages are conveyed. We need to communicate to teachers what evidence-based education is, and how to evaluate evidence that influences their practice. This is particularly pertinent in response to commercially available resources. In addition, we need to stress that studies are made accessible to teachers, either directly to the study publication or through summary documents, such as this report.

Additional resources

The study team has developed a free to access website that summarises the findings of this review. The website has a number of functions: 1) Video footage explaining evidence-based education, systematic reviews and RCTs and the importance of replication to generate bodies of evidence it is apparent that this area is in need of further research. In addition, only a small proportion of these identified studies specifically report replication. In addition, this review highlights the importance of replication to generate bodies of evidence it is apparent that this area is in need of further research. In addition, only a small proportion of these identified studies specifically report replication. In addition, this review indicates the importance of replication and the rigour of the trial. The current review observed that nearly all studies reported positive effects, but the majority of studies had issues with potential of bias. However, findings from these reviews should also be treated with caution due to limitations.

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www.ulster.ac.uk/mathsinterventions

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Summary tables for included studies
# Interventions to improve mathematical achievement in primary school-aged children

## Table 3: Summary of conceptual studies

<table>
<thead>
<tr>
<th>Author(s) and publication year</th>
<th>Study title</th>
<th>General focus of the study</th>
<th>Intervention summary</th>
<th>Age Group</th>
<th>Research method</th>
<th>Intensity</th>
<th>Outcome measure(s)</th>
<th>Outcome(s)</th>
<th>Country</th>
<th>Intervention resource requirement(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Al-ebous (2016)</td>
<td>Effect of the Van Hiele Model in Geometric Concepts Acquisition and Learning Transfer Effect of the First Three Grades Students in Jordan.</td>
<td>Conceptual understanding</td>
<td>The impact of using the Van Hiele model to inform the teaching of geometry. This model has five phases: visualisation, analysis, abstraction, deduction and rigour. The control group was taught using conventional methods.</td>
<td>6-8 year-olds</td>
<td>RCT</td>
<td>Not specified</td>
<td>Geometric concepts acquisition test (author generated)</td>
<td>The intervention led to significant improvements with the Van Hiele group outperforming the control group who were taught conventionally.</td>
<td>Jordan</td>
<td>Author developed materials</td>
</tr>
<tr>
<td>Baroody, Purpura, Eiland, Reid &amp; Paliwal (2016)</td>
<td>Does fostering reasoning strategies for relatively difficult basic combinations promote transfer by K-3 students?</td>
<td>Conceptual understanding</td>
<td>Assess whether computer-based training that focuses on the conceptual bases for two different reasoning strategies, namely subtraction as addition and use-10, improves mental arithmetic skills. A control drill condition was also used.</td>
<td>4-9 year-olds</td>
<td>RCT</td>
<td>7.5 weeks of preparation for all children then 12 weeks of computerised training. Two 30 min sessions per week.</td>
<td>Mental arithmetic test (author generated)</td>
<td>At posttest the subtraction as addition group outperformed the use-10 and drill group on arithmetic subtraction fluency. The use-10 group outperformed the subtraction as addition and control groups on addition problems.</td>
<td>USA</td>
<td>Author generated computerised tasks, computers</td>
</tr>
<tr>
<td>González-Castro, Cueli, Cabeza, Alvarez-Garcia &amp; Rodriguez (2014)</td>
<td>Improving basic math skills through integrated dynamic representation strategies.</td>
<td>Conceptual understanding</td>
<td>Assessing the impact of the implementation of an adaptive computerised Integrated Dynamic Representation strategy on informal and formal basic mathematical skills. The intervention involved participants identifying key concepts, visualising these concepts and integrating representations. Control participants experienced traditional teaching methods.</td>
<td>6-8 year-olds</td>
<td>RCT</td>
<td>45 50 minute sessions</td>
<td>Mathematical achievement was assessed Test of Early Mathematics Ability (TEMA-3, Ginsburg &amp; Baroody).</td>
<td>The experimental group displayed significant improvement in informal (numbers, comparisons, calculation and informal concepts) and formal skills (conventions and formal concept). There was no significant improvement in number facts or formal calculus when compared to the business as usual control group.</td>
<td>Spain</td>
<td>Specialist training for the teacher delivering the intervention. Tool software and computers</td>
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<tr>
<td>Hattikudur &amp; Alibali (2010)</td>
<td>Learning about the equal sign: Does comparing with inequality symbols help?</td>
<td>Conceptual understanding</td>
<td>Assess whether instruction that uses comparison of the equals sign to other relational symbols is better at conveying the relational aspect of the equals sign rather than pure instruction about the equals sign alone.</td>
<td>8-10 year-olds</td>
<td>RCT</td>
<td>30 mins</td>
<td>Equivalence problems test (author generated)</td>
<td>Children in the comparing condition displayed greater increases in conceptual understanding after compared with the direct instruction group and control group. They also showed better performance in assessments of knowledge of inequality symbols and inequality problem solving in comparison to the other two groups.</td>
<td>USA</td>
<td>Author generated practice sheets</td>
</tr>
<tr>
<td>McNeil, Chesney, Matthews, Fyfe, Peterson, Dunwiddie &amp; Wheeler (2012)</td>
<td>It pays to be organized: Organizing arithmetic fact practice around equivalent values facilitates understanding of math equivalence.</td>
<td>Conceptual understanding</td>
<td>Assess the impact of the structure of arithmetic fact practice on understanding of mathematical equivalence. Problems were either grouped by equivalent sums, grouped by iterative shared addends or no additional practice.</td>
<td>7-9 year-olds</td>
<td>RCT</td>
<td>7 weeks (100 min total)</td>
<td>Tests to assess equation asking, equation encoding and defining the equals sign; equipercentile, used in prior publications</td>
<td>The group that used facts organized by equivalent values showed better understanding of math equivalence than the other groups.</td>
<td>USA</td>
<td>Author generated workbook</td>
</tr>
<tr>
<td>Author(s) and publication year</td>
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<tr>
<td>McNeil, Fyfe &amp; Dunwiddle (2015)</td>
<td>Arithmetic practice can be modified to promote understanding of mathematical equivalence.</td>
<td>Conceptual understanding</td>
<td>Assess the effectiveness of modifying practice to teach the understanding of equivalence. The intervention group completed traditional workbooks (i.e., in operations = answer format; 4 + 3 = _). The control group completed traditional workbooks (i.e., including operations on the right hand side of the equals sign, the replacement of the sign with relational words and blocking of sums with the same answer).</td>
<td>7-8 year-olds</td>
<td>RCT</td>
<td>One off session</td>
<td>Author-generated tests were used to measure equation solving, and equation encoding skills. In addition, children were assessed on their ability to define the equal sign with an author-generated test. Computational fluency was assessed using a timed addition test (Gray, Bray, Soltaire, &amp; Salge, 1996) and the Math Computation subscale of the Iowa Test of Basic Skills test.</td>
<td>Children in the intervention group displayed better understanding of equivalence than the control group both at post-test and up to 6 months after the intervention. There was no effect of the intervention on computational fluency or performance on the Math Computation test.</td>
<td>USA</td>
<td>Author generated workbook</td>
</tr>
<tr>
<td>Paliwal (2013)</td>
<td>Fostering fluency with basic addition and subtraction facts.</td>
<td>Conceptual understanding</td>
<td>Assess the effectiveness of computerised structured training on the complement principle compared to unstructured subtraction practice or a control condition that used structured training on a different mathematical topic.</td>
<td>4-9 year-olds</td>
<td>RCT</td>
<td>12 weeks: 30 minute sessions twice per week</td>
<td>Author-generated computational shortcut task to gauge understanding of the complement principle. Children must be able to identify the shortcut to complete the problem accurately and quickly.</td>
<td>The structured subtraction group outperformed the other groups in knowledge of the complement principle and use of the principle.</td>
<td>USA</td>
<td>Author generated computer software, computers.</td>
</tr>
<tr>
<td>Park &amp; Nunes (2007)</td>
<td>The development of the concept of multiplication</td>
<td>Conceptual understanding</td>
<td>Assess the impact of multiplication by repeated addition or through correspondence.</td>
<td>5-6 year-olds</td>
<td>RCT</td>
<td>Two school days (part)</td>
<td>Author-generated workbook</td>
<td>Both groups showed significant progress in additive and multiplicative reasoning. The group taught by correspondence made more progress in multiplicative reasoning skills than the repeated addition group.</td>
<td>England</td>
<td>Author generated workbook</td>
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</table>
### Author(s) and publication year

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<thead>
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<tr>
<td>Ploger &amp; Hecht (2009)</td>
<td>Enhancing children’s conceptual understanding of mathematics through Chartworld software</td>
<td>Assessment of the efficacy of Chartworld computerised game for teaching arithmetic and number theory. The software allows children to make visual displays of models that can be manipulated.</td>
<td>8-9 year-olds</td>
<td>RCT</td>
<td>Experiment 1: 8 lessons of 30 mins, Experiment 2: 6 lessons of 45 mins</td>
<td>Structured interview and written test (author generated)</td>
<td>The specific details of these assessments were not recorded.</td>
<td>Experiment 1: The Chartworld group displayed significant benefits in terms of the skills assessed by the structured interview and the written test.</td>
<td>USA</td>
</tr>
<tr>
<td>Rutherford, Farkas, Duncan, Burchinal, Kibrick, Graham, Richland, Tran, Schneider, Duran &amp; Martinez (2014)</td>
<td>A randomized trial of an elementary school mathematics software intervention: Spatial-temporal Math</td>
<td>This study assessed the efficacy of Spatio-Temporal Math, a computerised teaching programme that teaches children the links between mathematical concepts through visualisation. A focus on spatial relationships is also included in the intervention. Participants were also recruited into a business as usual control group.</td>
<td>7-11 year-olds</td>
<td>RCT</td>
<td>Two years, with the intervention children receiving an additional 90 minutes of mathematics instruction per week</td>
<td>Mathematical achievement was assessed using the California Standard Tests.</td>
<td>The intervention produced a minimal increase in mathematics achievement over a one-year period for all intervention groups compared to the control group. There were no significant effects over the two year period.</td>
<td>USA</td>
<td>Professional development training for all teachers delivering the intervention. Spatio-Temporal Math software ($35 per student). Computers were also required to deliver the intervention.</td>
</tr>
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<tr>
<td>Hung, Sun &amp; Yu (2015)</td>
<td>The benefits of a challenge: student motivation and flow experience in tablet-based learning</td>
<td>Conceptual understanding</td>
<td>To assess the impact of an iPad application on learning and applying mathematics</td>
<td>8-9 year-olds</td>
<td>Quasi-experimental</td>
<td>The intervention consisted of a 40 minute session.</td>
<td>Self-efficacy for science, self-efficacy for technology, flow and feelings about the games were assessed through a questionnaire adapted from previous studies. Mathematics achievement was assessed by a teacher-generated test.</td>
<td>This intervention required tablet computers and the Motion Math: Hungry Fish application: <a href="https://motionmathgames.com/">https://motionmathgames.com/</a></td>
<td>Taiwan</td>
</tr>
<tr>
<td>Kaufman, Delazer, Pohl, Semenza &amp; Dowker (2005)</td>
<td>Effects of a specific numeracy educational program in kindergarten children: A pilot study</td>
<td>Conceptual understanding</td>
<td>This study compared the impact of a numeracy-specific intervention that focused on conceptual understanding and counting principles. The intervention was delivered in small groups and children were given opportunities to learn by trial and error. The control group was active and were trained in procedural skills. This training was unstructured.</td>
<td>5-6 year-olds</td>
<td>Quasi-experimental</td>
<td>15 minutes every other day for a full semester</td>
<td>Arithmetic skills were assessed using the Kaufman Assessment Battery for Children. Calculation subtest. In addition, an author-generated test was used to assess number processing and calculation.</td>
<td>Children in the experimental group showed significant learning in sequential calculation.</td>
<td>Austria</td>
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</tbody>
</table>
## A Systematic Review Interventions to improve mathematical achievement in primary school-aged children

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<tr>
<td>Sophian &amp; Madrid (2003)</td>
<td>Young Children’s Reasoning about Many-to-One Correspondences</td>
<td>Conceptual understanding</td>
<td>This study investigated the impact of many-to-one mapping training. Experiment 1 focused on the iterative nature of many-to-one correspondence (i.e., the multiplicative relationship when being told to place 3 flowers in each of 4 vases). The experimental group received training that focused on the relationship between large blocks and sets of smaller blocks (i.e., 3 small blocks for each large block, etc), the control group compare heights of stacks of blocks (i.e., to observe when a stack of small blocks reached the same height as two large blocks).</td>
<td>5-7 year-olds</td>
<td>Quasi-experimental</td>
<td>One off session to deliver a brief intervention (10-15 minutes)</td>
<td>Children's many-to-one correspondence skills were assessed by an author-generated pictorial ratio completion problem test, in which children had to complete some multiplicative relationship to be the same on the left and right side of an equation.</td>
<td>Overall, these experiments provided limited evidence to suggest that the focus of the intervention aided learning, substantial gains were only observed for 7 year-olds- this was driven by large improvements in a small subset of the participants.</td>
<td>USA</td>
<td>Wooden 2D blocks of varying sizes</td>
</tr>
<tr>
<td>Fyfe, DeCaro, &amp; Rittle-Johnson (2014)</td>
<td>An alternative time for telling: When conceptual instruction prior to problem solving improves mathematical knowledge.</td>
<td>Conceptual</td>
<td>Children were assigned to either instruct-solve or solve-instruct intervention groups. In the instruction component, children were taught the relational meaning of the equals sign through equations. In the problem solving component, children completed standardized arithmetic problems and math equivalence problems. Children had to explain how they reached their answer. Children received feedback.</td>
<td>7-9 year-olds</td>
<td>Quasi-experimental</td>
<td>One off session lasting 50 minutes (including outcome assessment)</td>
<td>Author-generated mathematics equivalence test, adapted from previous publications. This test focused on the meaning of the equals sign and equation structure.</td>
<td>Children who received conceptual training before problem solving led to higher procedural and conceptual knowledge gains. Although, the solve-instruct group did also improve with time.</td>
<td>USA</td>
<td>Author generated problems were generated to enable problem solving.</td>
</tr>
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### A Systematic Review Interventions to improve mathematical achievement in primary school-aged children

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<tbody>
<tr>
<td>Durkin &amp; Rittle-Johnson (2012)</td>
<td>The effectiveness of using incorrect examples to support learning about decimal magnitude.</td>
<td>Magnitude</td>
<td>Assessing the efficacy of comparing incorrect and correct examples on learning about decimal magnitude, compared to comparing correct examples.</td>
<td>9-11 year-olds</td>
<td>RCT</td>
<td>25 mins</td>
<td>Author generated conceptual and procedural test for completing number line estimation</td>
<td>The incorrect condition helped students learn correct procedures and key concepts more than the correct condition, including reducing misconceptions.</td>
<td>USA</td>
<td>Resource packet—author generated</td>
</tr>
<tr>
<td>Fazio, Kennedy &amp; Siegler (2016)</td>
<td>Improving children’s knowledge of fraction magnitudes.</td>
<td>Magnitude</td>
<td>Assessing the impact of a computerised fraction game on children’s understanding of fraction magnitudes.</td>
<td>9-11 year-olds</td>
<td>RCT</td>
<td>1 off session (15 minutes)</td>
<td>Author generated number line estimation test, magnitude comparison test and fraction recall test.</td>
<td>Across two studies, evidence suggested that the intervention increased children’s number line estimation, magnitude comparison, and recall of fraction information performance. No improvement was observed in the control group’s performance.</td>
<td>USA</td>
<td>Catch The Monster computerised game—adapted by authors, computers</td>
</tr>
<tr>
<td>Yoon (2015)</td>
<td>The Effects of Digital Tools on Third Graders’ Understanding of Concepts and Development of Skills in Multiplication.</td>
<td>Magnitude</td>
<td>Assessing the impact of digital intervention tools on multiplication skills and number sense. Participants were assigned to either a virtual number line intervention, a dynamic hundreds chart (i.e. a morphable multiplication chart) or a control reading group.</td>
<td>8-9 year-olds</td>
<td>RCT</td>
<td>4 sessions over 4 weeks</td>
<td>Author generated mathematics equivalence test, adapted from previous publications. This test focused on the meaning of the equals sign and equation structure.</td>
<td>Number skills and understanding were assessed using sub-tests from the mClass: Math standardised test. These sub-tests assessed participants’ knowledge and quantity discrimination skills. A timed multiplication test was also administered. This was author generated with specific questions based on those in an age-appropriate textbook. An understanding task also assessed children’s understanding of multiplication from different conceptual models.</td>
<td>USA</td>
<td>MathemAntics™ software developed at Teachers College, Columbia University. Computers were also required to deliver the intervention.</td>
</tr>
</tbody>
</table>
This study assessed the impact of two computer-based interventions on mathematical achievement in primary school-aged children. The effect of a computerised game on children's engagement and perceptions of learning was also assessed. Specifically, the Graphical Partitioning Model software was used- this is a computerised tool on achievement, fraction knowledge, fraction equivalence, fraction addition and subtraction. An author-generated questionnaire was also administered to assess attitudes.

Table 5:
Summary of basic number skills studies

<table>
<thead>
<tr>
<th>Author(s) and publication year</th>
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<th>Intervention resource requirement(s)</th>
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<tbody>
<tr>
<td>Kong (2014)</td>
<td>An evaluation study of the use of a computerised cognitive support tool in a classroom setting for promoting classroom-based dialogic interaction</td>
<td>Magnitudes</td>
<td>This study assessed the effect of a computerised cognitive support tool on achievement, engagement and perceptions of learning for children in Italy. Specifically, the Graphical Partitioning Model software was used- this is a computerised tool in a one-to-one classroom setting. The control group was also assessed.</td>
<td>9-10 year-olds</td>
<td>Quasi-experimental</td>
<td>11 teaching sessions 455 minutes</td>
<td>Fraction knowledge was assessed using an author-generated test on fraction equivalence, fraction addition and subtraction. An author-generated questionnaire was also administered to assess attitudes.</td>
<td>The cognitive tool increased student engagement. Children in the experimental group performed better than the control group in fraction learning. Children reported positive attitudes towards the tool.</td>
<td>Hong Kong</td>
<td>The Graphical Partitioning Model software was used- this is a computerised tool on achievement, fraction knowledge, fraction equivalence, fraction addition and subtraction. An author-generated questionnaire was also administered to assess attitudes.</td>
</tr>
<tr>
<td>Khun &amp; Holling (2014)</td>
<td>Number sense or working memory? The effect of two computer-based interventions on mathematical skills in elementary school</td>
<td>enhanced or reduced</td>
<td>Both training groups displayed significant improvement in working memory or number sense. The achievement of the experimental group was significantly higher than the control group.</td>
<td>69 year-olds</td>
<td>RCT</td>
<td>20 mins per day for 15 days</td>
<td>Comparing the impact of number sense versus working memory training on arithmetic achievement. The number sense training focused on number line understanding and comparison. The working memory training focused on working memory skills, such as remembering spatial locations. A control group was also recruited.</td>
<td>RCT</td>
<td>Both training groups displayed significant improvement in working memory or number sense. The achievement of the experimental group was significantly higher than the control group.</td>
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<tr>
<td>Mascio, Agnoli, &amp; Nervi, Sale &amp; Kissi (2013)</td>
<td>The Development of Improvement Mathematical Abilities: The Impact of Paper and Pencil versus Paper and Computerised Interventions for Preschool Children</td>
<td>The impact of paper and pencil versus computerised training. The impact of paper and pencil was play-based focusing on Arabic number knowledge, such as sequencing understanding of the number sequence group was also assessed.</td>
<td>3 year-olds</td>
<td>RCT</td>
<td>Computer group: 30 mins.</td>
<td>Numerical knowledge was assessed using the Numeracy Mathematics Test. 2011. Both groups showed significant improvement in numerical knowledge over the number sequence group. There was no significant difference in performance between the two intervention groups.</td>
<td>RCT</td>
<td>Both training groups showed significant improvement in numerical knowledge over the number sequence group. There was no significant difference in performance between the two intervention groups.</td>
<td>Italy</td>
<td>Training material from &quot;Intelligence numerale&quot; (Lucangeli, Poli, &amp; Molin 2003) and &quot;Comprensione numerale&quot; (Lucangeli, Poli, &amp; Molin 2010) either in paper and pencil format or in computerised format autor generated.</td>
</tr>
<tr>
<td>Author(s) and publication year</td>
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<tr>
<td>Obersteiner, Reiss &amp; Ufer (2013)</td>
<td>How training on exact or approximate mental representations of number can enhance first-grade students’ basic number processing and arithmetic skills.</td>
<td>Basic number skills</td>
<td>This study aimed to assess the efficacy of exact, approximate or both exact and approximate number processing computer game on arithmetic achievement. A control group was also assessed.</td>
<td>6 year-olds</td>
<td>RCT</td>
<td>6 training sessions of 30 minutes each over a period of 4 weeks</td>
<td>Improvement was displayed on the trained skill (i.e. exact or approximate skills) but no cross over was observed between intervention groups. Achievement in arithmetic was higher in the experimental groups than the control group at post-test.</td>
<td>Germany</td>
<td>Computerised games based on &quot;The Number Race&quot; (Wilson et al., 2006) open-source software: <a href="http://www.unicog.org/main/pages.php?page=NumberRace">http://www.unicog.org/main/pages.php?page=NumberRace</a></td>
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<tr>
<td>Praet &amp; Desoete (2014)</td>
<td>Enhancing young children’s arithmetic skills through non-intensive, computerised kindergarten interventions: A randomised controlled study.</td>
<td>Basic number skills</td>
<td>Assessing the efficacy of computerised interventions on children’s early mathematical skills. Children were assigned to either a counting or number comparison intervention. There was also a control group.</td>
<td>5 years old</td>
<td>RCT</td>
<td>9 x 25 min session</td>
<td>Children in the number comparison and counting intervention group performed better in arithmetic than the control group. Both intervention groups had a better number knowledge compared to the control group. Children in the counting intervention group did better than those in the number comparison group on calculation. There were no group differences in number line estimation performance at follow up.</td>
<td>Belgium</td>
<td>Computer Assisted Intervention serious games source not specified, trained professionals to deliver the intervention</td>
<td></td>
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<tr>
<td>Sood &amp; Mackey (2015)</td>
<td>Examining the effects of number sense instruction on mathematics competence of kindergarten students</td>
<td>Assessing the efficacy of number sense instruction on general classroom mathematical skills. The number sense instruction intervention followed a structured programme focusing on key topics, such as more and less, part-whole relationships, and business. A control group was also assessed.</td>
<td>All children received 60 minutes of mathematics instruction for 20-30 mins 5 days a week.</td>
<td>Mean age: 5.6 years-old</td>
<td>RCT</td>
<td>All children received 60 minutes of mathematics instruction for 20-30 mins 5 days a week.</td>
<td>Both groups made significant gains. For the combined group on the EN-CBM significant improvement for 3 of the 6 sub-tests was reported. There were also significant improvements on all of the 5 subtests on the Number Sense test. The combined intervention group outperformed the control group at delayed post-test on the majority of tests.</td>
<td>USA</td>
<td>Number sense program adapted from existing sources (Bell, Bell, Bretzlauf, Dellard, Hartfeild, Isaacs, et al., 2004; Columba, Kim, &amp; Moe, 2005; Van de Walle, 2007) or author generated tests.</td>
<td></td>
</tr>
<tr>
<td>Hyde, Khanum &amp; Spelke (2013)</td>
<td>Brief non-symbolic, approximate number practice enhances subsequent exact symbolic arithmetic in children.</td>
<td>In Experiment 1 children experienced either a symbolic addition task, a line-length addition task, a non-symbolic comparison task or a brightness comparison task. In Experiment 2 first assigned children to either a non-symbolic addition task or brightness comparison task. Then children were either asked to complete sentence completion tasks or symbolic addition tasks.</td>
<td>6-7 year-olds</td>
<td>Quasi-experimental</td>
<td>In Experiment 1 children’s symbolic addition skills were assessed using an author-generated test. In Experiment 2 participants were assessed using the Panamath computer game. In Experiment 2 participants were asked to complete sentence completion tasks or symbolic addition tasks.</td>
<td>In Experiment 1 children who were in either non-symbolic comparison or symbolic addition displayed faster response times for symbolic addition tasks. In Experiment 2 children who experienced non-symbolic comparison training were more accurate on the symbolic mathematics problems than children who completed brightness comparison tasks. There was no group difference in sentence completion.</td>
<td>USA</td>
<td>Author-generated computerized tasks and computers.</td>
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</table>
Interventions to improve mathematical achievement in primary school-aged children

**Author(s) and publication year**: Khumari, Hunt, Swail, & Hyde (2014)

**Study title**: Effects of non-symbolic approximate number practice on symbolic arithmetic skills in primary school-aged Pakistani children.

**General facts of the study**
- **Age Group**: 6-year-olds
- **Research method**: Basic number skills
- **Intensity**: 6-day training
- **Outcome measure(s)**: Symbolic addition was assessed using an author-generated test. Non-symbolic accuracy was assessed using the Panamath task.
- **Country**: Pakistan
- **Intervention resource requirement(s)**: The intervention was delivered via a computerised task developed by the researchers.

**Intervention summary**
- **Group**: Quasi-experimental
- **One off training session**
- **Grossi-experimental**

**Outcome(s)**
- Children in the non-symbolic training condition performed better than those in the line length condition. Experiment 2 indicated that number line estimation performance was enhanced in the non-symbolic training group compared to a control group.

**Author(s) and publication year**: Bakker, van der Maas, & Kroesbergen (2015)

**Study title**: Effects of playing mathematics computer games on primary school children’s multiplicative reasoning ability.

**General facts of the study**
- **Age Group**: 8-10-year-olds
- **Research method**: RCT
- **Intensity**: 2 sessions data on a computer game software available for free from: http://www.fisme.science.uu.nl/subsets/publicaties/science.uu.nl/www.fisme.rekenweb_en/
- **Country**: Netherlands
- **Intervention resource requirement(s)**: Computerised game software.

**Intervention summary**
- **Group**: Three components of mathematical reasoning were assessed: knowledge of number relations only, multiplication operations and insight into multiplicative relations.
- **One off session**

**Outcome(s)**
- School-based intervention group improved in insight into multiplicative relations only.
- Results were generated.

**Author(s) and publication year**: Barnett, Pratte, & Make (2015)

**Study title**: Effect of modifying the intervention duration: Retention rate data while practicing single-digit multiplication facts.

**General facts of the study**
- **Age Group**: 5-10-year-olds
- **Research method**: RCT
- **Intensity**: 8-10 sessions
- **Country**: USA
- **Intervention resource requirement(s)**: Flash card game software.

**Intervention summary**
- **Group**: Multiplication facts test was administered flash cards. Each fact correctly answered within 2 sec was classified as being recollected.
- **One off session**

**Outcome(s)**
- The total recall group (those who experienced multiplication facts, skills in number relations only, multiplication operations and insight into multiplicative relations).
- Results were generated.

**Author(s) and publication year**: Kwong, Maki, & Zaslofsky (2015)

**Study title**: Practice for fluency.

**General facts of the study**
- **Age Group**: 2-11 year-olds
- **Research method**: Multiplication facts test was administered flash cards. Each fact correctly answered within 2 sec was classified as being recollected.

**Intervention summary**
- **Group**: Three components of mathematical reasoning were assessed: knowledge of number relations only, multiplication operations and insight into multiplicative relations.
- **One off session**

**Outcome(s)**
- School-based intervention group improved in insight into multiplicative relations only.
- Results were generated.

**Author(s) and publication year**: Burns, Robitzsch, Maki, & Zaslofsky, Panhuize, & den Heuvel-Bakker, van (2015)

**Study title**: Assess the impact of varying intervention set size (either 2, 8 or a personalized number of multiplication facts) with acquisition rate for the amount that a child can learn within a season.

**General facts of the study**
- **Age Group**: 6-8-year-olds
- **Research method**: RCT
- **Intensity**: Years
- **Country**: USA
- **Intervention resource requirement(s)**: Flash card game software.

**Intervention summary**
- **Group**: Three components of mathematical reasoning were assessed: knowledge of number relations only, multiplication operations and insight into multiplicative relations.
- **One off session**

**Outcome(s)**
- School-based intervention group improved in insight into multiplicative relations only.
- Results were generated.

**Author(s) and publication year**: Bertletti & Spelke, Hanif, & Khanum (2016)

**Study title**: Effects of study of the focus length addition).

**General facts of the study**
- **Age Group**: Year-olds
- **Research method**: Author generated test.
- **Intensity**: Author generated test.
- **Outcome measure(s)**: Number line estimation was assessed using an author-generated test.
- **Country**: Pakistan
- **Intervention resource requirement(s)**: The intervention was delivered via a computerised task developed by the researchers.

**Intervention summary**
- **Group**: Quasi-experimental
- **One off training session**
- **Grossi-experimental**

**Outcome(s)**
- Children in the non-symbolic training condition performed better than those in the line length condition. Experiment 2 indicated that number line estimation performance was enhanced in the non-symbolic training group compared to a control group.

**Author(s) and publication year**: Hyde (2016)

**Study title**: Computerised one-off intervention.

**General facts of the study**
- **Age Group**: Year-olds
- **Research method**: Grossi-experimental
- **Intensity**: One off training session
- **Outcome measure(s)**: Symbolic addition was assessed using an author-generated test. Non-symbolic accuracy was assessed using the Panamath task.
- **Country**: Pakistan
- **Intervention resource requirement(s)**: The intervention was delivered via a computerised task developed by the researchers.

**Intervention summary**
- **Group**: Quasi-experimental
- **One off training session**
- **Grossi-experimental**

**Outcome(s)**
- Children in the non-symbolic training condition performed better than those in the line length condition. Experiment 2 indicated that number line estimation performance was enhanced in the non-symbolic training group compared to a control group.

**Table 6: Summary of practice for fluency studies**

<table>
<thead>
<tr>
<th>Author(s) and publication year</th>
<th>Study title</th>
<th>General facts of the study</th>
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<tr>
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<td>Assess the impact of varying intervention set size (either 2, 8 or a personalized number of multiplication facts) with acquisition rate for the amount that a child can learn within a season.</td>
<td>Assess the impact of varying intervention set size (either 2, 8 or a personalized number of multiplication facts) with acquisition rate for the amount that a child can learn within a season.</td>
<td>Author generated test.</td>
<td>5-7 year-olds</td>
<td>RCT</td>
<td>8 sessions</td>
<td>Multiplication facts test was administered flash cards. Each fact correctly answered within 2 sec was classified as being recollected.</td>
<td>School-based intervention group improved in insight into multiplicative relations only.</td>
<td>USA</td>
<td>Flash card game software.</td>
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</table>

**Table 6: Summary of practice for fluency studies**

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<td>Author generated test.</td>
<td>5-7 year-olds</td>
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<td>8 sessions</td>
<td>Multiplication facts test was administered flash cards. Each fact correctly answered within 2 sec was classified as being recollected.</td>
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</tr>
<tr>
<td>Reuter, Anthony, Clements &amp; Samara (2016)</td>
<td>Improving mathematics learning of underprivileged students through computer-aided instruction.</td>
<td>Practice fluency</td>
<td>Assess the impact of the Building Blocks Software on mathematical achievement, compared to a computer-assisted learning programme focusing on phonological awareness. The Building Blocks software focuses on developing numeracy and geometry skills, specifically fluency and sequencing.</td>
<td>5-7 years olds</td>
<td>RCT</td>
<td>21 weeks of 90 mins per week</td>
<td>Woodcock Johnson III Test of Achievement, Applied Problems added to assess problem solving and the, Early Maths Assessment (EMMA) assessed numeracy skills, with additional measuring number recognition and subitizing, composition of number, comparison of number, and subitizing.</td>
<td>USA</td>
<td>Building Blocks software. Computers were also required to deliver the intervention.</td>
<td></td>
</tr>
<tr>
<td>Cohen (2012)</td>
<td>The Effectiveness of a Technology Integration Program: Metropolis Elementary Mathematics Program, Math 360.</td>
<td>Practice fluency</td>
<td>Assessed the impact of a supplementary program Mad Dog Math intervention that provided additional teaching focusing on retrieval fluency. This computerised program is adaptive and provides learners with feedback.</td>
<td>7-9 year-olds</td>
<td>Quasi-experimental</td>
<td>10 weeks</td>
<td>REMA subtests</td>
<td>California Standard Test of mathematical achievement</td>
<td>USA</td>
<td>Math computer. Computers were also required to deliver the intervention.</td>
</tr>
<tr>
<td>Van der Ven &amp; Segers, Takahama &amp; Ven (2017)</td>
<td>Effects of a tablet intervention on simple arithmetic fluency in first graders.</td>
<td>Practice fluency</td>
<td>This study assessed the impact of a tablet game on children’s arithmetic fluency. The experimental group played the racing car iPad game, and the control group watched videos as usual. Children were assessed immediately after the intervention and 12 weeks later.</td>
<td>4-5 years olds</td>
<td>Quasi-experimental</td>
<td>5 week intervention</td>
<td>Arithmetic skills were measured using an author-generated test. The test was time limited and the game motivation and attitude towards mathematics was business as usual. Children were assessed immediately after the intervention and 12 weeks later.</td>
<td>Netherlands</td>
<td>The experimental group displayed more efficiency on non-symbolic subtraction than the control group. There was no effect on symbolic efficiency. There was also no significant group effect after motivation.</td>
<td></td>
</tr>
</tbody>
</table>
Interventions to improve mathematical achievement in primary school-aged children

Carrié, Deshusses, Gamo, & Richard (2010)

Study title: Fourth Grade Strategies in solving arithmetic problems by semantic strategy use

Method: Quasi-experimental

Intensity: 12 days, 60 minutes per day

Age Group: 9-10 year-olds

Outcome: author-generated

Outcome measure(s): No specific measures were required for this intervention

Country: France

Intervention summary: This intervention involved providing students with problem-solving tests and encouraging them to use appropriate strategies. The results of Experiment 1 suggest that the comparison between the two intervention groups was not significant.

Outcome(s): There were no significant differences at posttest.

Intensity: 40 half-hour sessions over 20 weeks

Country: USA

Intervention resource requirement(s): Computers were required for this intervention.

Author(s) and publication year: Carrié, Deshusses, Gamo, & Richard (2010)

Zutaut (2002)

Study title: Arithmetic Addition and Subtraction Skills Among Primary Grade Students

Method: Quasi-experimental

Intensity: 12 days, 60 minutes per day

Age Group: 6-7 year-olds

Outcome: author-generated

Outcome measure(s): There were no significant group differences at posttest.

Country: USA

Intervention summary: This intervention involved providing students with problem-solving tests and encouraging them to use appropriate strategies. The results of Experiment 1 suggest that the comparison between the two intervention groups was not significant.

Outcome(s): There were no significant differences at posttest.

Intensity: 40 half-hour sessions over 20 weeks

Country: USA

Intervention resource requirement(s): Computers were required for this intervention.

Author(s) and publication year: Zutaut (2002)

Carr, Haase, Stroud, & Royer (2009)

Study title: Combined fluency and creative strategies improves mathematics achievement in early elementary school

Method: RCT

Intensity: 40 half-hour sessions over 20 weeks

Age Group: 7-8 year-olds

Outcome: Cognitive Aptitude Assessment System was used to measure mathematical fluency. An author generated test to assess creative strategy use was also required. A computer-generated test to deliver the intervention was used to measure strategy use in addition and subtraction problems. The intervention achievement was assessed using an author-generated test pooling existing and computer-generated tasks. The inclusion of these tasks was required to deliver the intervention.

Outcome measure(s): There were no significant differences at posttest.

Country: USA

Intervention resource requirement(s): Computers were also required to deliver the intervention.

Author(s) and publication year: Carr, Haase, Stroud, & Royer (2009)

Table 1: Summary of strategy use studies
<table>
<thead>
<tr>
<th>Author(s) and publication year</th>
<th>Study title</th>
<th>General focus of the study</th>
<th>Intervention summary</th>
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<tr>
<td>Mason &amp; Soriano (2004)</td>
<td>Enhancing students' mathematical beliefs: An experimental study</td>
<td>To assess the efficacy of cultural change in the classroom towards actively doing mathematics, with a focus on problem solving through representation and staged problem solving</td>
<td>Children were taught to reflect on problem solving strategies in relation to their appropriateness. A control group was also assessed.</td>
<td>10 years old</td>
<td>RCT</td>
<td>12 sessions (1.5 hour per session) over a period of 3 months</td>
<td>An author generated word problem solving test developed using an author generated word problem solving strategy. Children reported lower perceived effort and understanding than the control group.</td>
<td>Italy</td>
<td>Mathematical problem solving teaches cultural source</td>
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</tr>
<tr>
<td>Chiu, Chau, Chong, &amp; Ng (2005)</td>
<td>Effect of Training in Math Metacognitive Strategy on Fractional Achievement of Nigerian Schoolchildren</td>
<td>To assess the effectiveness of training in math metacognitive strategies following a learning strategy model. The experimental group was compared to a control group.</td>
<td>Author generated fraction achievement test developed from textbook questions</td>
<td>11 years old</td>
<td>RCT</td>
<td>4 weeks of training</td>
<td>The experimental group outperformed the control group both in test achievement in fractional mathematics</td>
<td>Nigeria</td>
<td>Author generated math Metacognitive Training Programme</td>
<td></td>
</tr>
<tr>
<td>Stendel, Gorringe, Seh, &amp; Hasbani (2007)</td>
<td>A comparison of single and multiple strategies in improving elementary school students' mathematical problem solving achievement.</td>
<td>Assess the difference in impact of single strategy instruction compared to multiple instruction in improving mathematical problem solving and mathematics achievement.</td>
<td>Author generated mathematical word problem solving test. The 3-week intervention was used to assess mathematics problem solving and problem solving. Base-line pre-test mathematics fluency was assessed using a measure by Fuchs, Hamlet, &amp; Fuchs (1998). Standardized mathematics achievement was assessed with the Pennsylvania System of School Assessment (PSSA) Mathematics test. Single strategy instruction led to more favourable gains in mathematical problem solving than multiple strategy instruction, the same pattern was observed for the PSSA standardized test. There were no significant group effects for improvement in computation.</td>
<td>8-9 year-olds</td>
<td>RCT</td>
<td>25 mins x 5 times a week</td>
<td>Mathematical word problems - author generated</td>
<td>USA</td>
<td>Mathematical word problems - author generated</td>
<td></td>
</tr>
<tr>
<td>Kaduvettoor, Adams &amp; Haria, Leh, Griffin, &amp; Jitendra (2007)</td>
<td>Study title: Intervention to improve mathematical achievement in primary school-aged children</td>
<td>To assess the difference in impact of single strategy instruction compared to multiple instruction in improving mathematical problem solving and problem solving. Base-line pre-test mathematics fluency was assessed using a measure by Fuchs, Hamlet, &amp; Fuchs (1998). Standardized mathematics achievement was assessed with the Pennsylvania System of School Assessment (PSSA) Mathematics test. Single strategy instruction led to more favourable gains in mathematical problem solving than multiple strategy instruction, the same pattern was observed for the PSSA standardized test. There were no significant group effects for improvement in computation.</td>
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<td>8-9 year-olds</td>
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<td>Jitendra (2008)</td>
<td>Word problem solving in inclusive third-grade mathematics classrooms</td>
<td>Strategy use</td>
<td>This study compared the performance of students who received a strategy-based or a general strategy intervention. The strategy group used general problem-solving procedures, whereas the control group used a general strategy instruction. The intervention was delivered over 18 weeks, with one session per week.</td>
<td>8-9 years</td>
<td>Quasi-experimental</td>
<td>The study took place over 20 days, one day per week.</td>
<td>Belgium</td>
<td>No specific materials were required.</td>
<td>The strategy group improved their problem-solving skills, and the control group did not.</td>
<td>Mathematics problem solving and computation skills.</td>
</tr>
<tr>
<td>Griffin &amp; Jinderia (2008)</td>
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<tr>
<td>Hirza, Kusumah &amp; Zulkardi (2014)</td>
<td>Improving intuition skills with realistic mathematics education</td>
<td>Strategy use</td>
<td>This study compared Realistic Mathematics Education (RME) to traditional mathematical instruction. RME connects mathematical learning to reality through applied problem solving, applying new strategies. The broad aim was to improve intuition in mathematics problem solving.</td>
<td>11-12 year-olds</td>
<td>Quasi-experimental</td>
<td></td>
<td>Children were assessed on their mathematics intuition ability.</td>
<td>The source of this assessment is unclear.</td>
<td>Indonesia</td>
<td>The required resources for this intervention are not reported.</td>
</tr>
<tr>
<td>Sulak (2010)</td>
<td>Effect of problem solving strategies on problem solving achievement in primary school mathematics</td>
<td>Strategy use</td>
<td>This study assessed the impact of problem solving training that focused on strategies compared to a traditional instruction control group.</td>
<td>7-8 year-olds</td>
<td>Quasi-experimental</td>
<td>14 weeks</td>
<td>Children completed two author-generated problem-solving tests. These tests were administered in the middle and end of the intervention. Qualitative data was also gathered.</td>
<td>Children in the experimental group showed significantly better strategy use than the control group.</td>
<td>Turkey</td>
<td>Resource requirements are unclear.</td>
</tr>
<tr>
<td>Poland &amp; van Oers (2007)</td>
<td>Effects of schematising on mathematical development</td>
<td>Strategy use</td>
<td>This study assessed whether an intervention to encourage schematising (drawing dynamic explanatory diagrams to aid problem solving) would lead to better mathematical achievement 2 years later. Children were assigned to either an experimental schematizing group, who were taught through play-based activities, or a business as usual control group.</td>
<td>5-6 year-olds</td>
<td>Quasi-experimental</td>
<td></td>
<td></td>
<td>Children's schematizing abilities were assessed using an author-generated test at the beginning of the intervention. 8 months after the intervention the mathematical achievement was assessed using a national standardized test, the CITO.</td>
<td>Netherlands</td>
<td>Teacher-trainer support was provided, the teacher and trainer observed children's activities in order to plan new activities.</td>
</tr>
</tbody>
</table>
Table 8: Summary of manipulatives studies

### Authors and publication year
- **Barnes, Allman, Sullivan, & Spivak (2011)**
  - Study title: Manipulatives: Assess the impact of mental abacus skills on primary school-aged children
  - General focus of the study: Assess whether the intervention of mental abacus instruction can improve mathematical achievement in primary school-aged children
  - Age Group: 6-year-olds
  - Research method: RCT
  - Intensity: 10 weeks, 30 mins per week
  - Outcome measure(s): Multilevel analysis
  - Outcome(s): Significant improvement in students' performance on mental abacus calculation tests compared to a control group.
  - Country: Belgium
  - Intervention resource requirement(s): A control group was used. Comparison data were taken from the control group.

- **Carette, Rey, Szucs, Coche, Gabriel, Frank (2016)**
  - Study title: The effects of using digital photographs with Geometer’s Sketchpad at 4th grade
  - General focus of the study: Assess whether the intervention of using digital photographs with Geometer’s Sketchpad can improve students’ understanding of fractions
  - Age Group: 6-year-olds
  - Research method: RCT
  - Intensity: 26 months, 2 weeks per month
  - Outcome measure(s): Math Fluency subtest of the WJ-II Calculation, a traditional calculation test
  - Outcome(s): Significant improvement in students’ performance on the Math Fluency subtest compared to a control group.
  - Country: China
  - Intervention resource requirement(s): A control group was used. Comparison data were taken from the control group.

- **Chen, & Staiger (2012)**
  - Study title: A Systematic Review: Interventions to improve mathematical achievement in primary school-aged children
  - General focus of the study: Assess the effectiveness of various interventions on improving mathematical achievement in primary school-aged children
  - Age Group: 6-year-olds
  - Research method: RCT
  - Intensity: 9 months, 2 weeks per month
  - Outcome measure(s): WIAT-III and two subtest of the WJ-II Calculation
  - Outcome(s): Significant improvement in students’ performance on the WIAT-III and WJ-II Calculation compared to a control group.
  - Country: China
  - Intervention resource requirement(s): A control group was used. Comparison data were taken from the control group.
This study assessed the impact of computer and manipulative interventions to improve mathematical achievement in primary school-aged children. Children were assigned to a manipulative intervention group or a computerized intervention group (children used a computerized manipulative that transformed from a unitized model to a continuous presentation). Children in the manipulative group transformed the manipulative from a unitized model to a continuous presentation. Children in the computerized intervention group performed tasks using a computerized manipulative. The computerized manipulative was adapted from an author-generated Snappet (MIT) tutor (MIT). The results show that the manipulation tutor system was significantly more helpful to the students than the conventional mathematics from the conventional web-based test in terms of learning mathematics than conventional computer-based tutor. Computers were also required to deliver the intervention.
<table>
<thead>
<tr>
<th>Author(s) and publication year</th>
<th>Study title</th>
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<th>Outcome(s)</th>
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<th>Intervention resource requirement(s)</th>
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<tr>
<td>Pyle &amp; Rittle-Johnson (2014)</td>
<td>The benefits of computer-generated feedback for mathematics problem solving</td>
<td>Feedback</td>
<td>An examination of the impact of computer-generated feedback on mathematical problem solving</td>
<td>7-8 year-olds</td>
<td>RCT</td>
<td>25 mins</td>
<td>Author adapted self-assessment of students’ reflection on their performance made them feel. An adapted version of a previously published tool by the authors (Pyle, Rittle-Johnson et al., 2011) was used to assess equation problem solving.</td>
<td>Immediate feedback had the largest impact on learning. Summative feedback also improved learning compared to no feedback. Interpersonal and reflective effect of feedback on children with high prior knowledge was observed. Children with low prior knowledge benefitted from both immediate and summative feedback, children with high prior knowledge did not benefit from either intervention.</td>
<td>USA</td>
<td>Author generated computerised problem-solving task. Computers were also required to deliver the intervention.</td>
</tr>
<tr>
<td>Chen &amp; Huang (2014)</td>
<td>Learning through computer-assisted learning activities</td>
<td>Technology engagement</td>
<td>Scaffolding game-based learning</td>
<td>Age 8-11</td>
<td>RCT</td>
<td>10 days</td>
<td>Author generated problem-solving assessment</td>
<td>No significant gains in problem solving were observed. However, the Study and Play group performed better in the post-test than the control group in the pre-test condition reduced the participants’ perceived learning. The introduction of the scaffold did not impact on enjoyment or flow.</td>
<td>Israel</td>
<td>Computers were also required to deliver the intervention.</td>
</tr>
<tr>
<td>Barzilai &amp; Blau (2014)</td>
<td>Scaffolding game-based learning for engagement</td>
<td>Technology engagement</td>
<td>Test the impact of a business simulation game with additional scaffolding</td>
<td>Age 8-11</td>
<td>RCT</td>
<td>10 days</td>
<td>Author generated problem-solving assessment</td>
<td>No significant gains in problem solving were observed. However, the Study and Play group performed better in the post-test than the control group in the pre-test condition reduced the participants’ perceived learning. The introduction of the scaffold did not impact on enjoyment or flow.</td>
<td>Israel</td>
<td>Computers were also required to deliver the intervention.</td>
</tr>
</tbody>
</table>

Table 10: Summary of technology for engagement studies
### Author(s) and publication year

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<tr>
<th>Study Title</th>
<th>General focus of the study</th>
<th>Intervention summary</th>
<th>Age Group</th>
<th>Research method</th>
<th>Intensity</th>
<th>Technology for engagement</th>
<th>Country</th>
<th>Intervention resources required</th>
<th>Outcome(s)</th>
<th>Measure(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ken &amp; Ke (2016)</td>
<td>Effects of gamelike learning tasks on Opaline-supported virtual environment on mathematical performance</td>
<td>Math Blaster</td>
<td>6-7 year-olds</td>
<td>RCT</td>
<td>45 minutes</td>
<td>Author generated</td>
<td>Both the experimental and control group improved in their math learning, but the increase was significantly greater for the experimental group.</td>
<td>USA</td>
<td>Similar to the study titles above.</td>
<td>Increase was greater for the experimental group.</td>
</tr>
<tr>
<td>Shults (2000)</td>
<td>Reading For Grades: Computer A Companion of Traditional Instruction and Computer Enhanced Instruction</td>
<td>Computer Enhanced</td>
<td>6-7 year-olds</td>
<td>Quasi-experimental</td>
<td>90 minutes</td>
<td>Implementation of traditional instruction was computerised.</td>
<td>Netherlands</td>
<td>Similar to the study titles above.</td>
<td>Increase was greater for the experimental group.</td>
<td>Log books and questionnaires to measure the intervention.</td>
</tr>
<tr>
<td>de Kock &amp; Hendriksen (2013)</td>
<td>Can teachers in primary education implement a multimedia computer programme to improve problem solving in their mathematics classroom?</td>
<td>Computer Enhanced</td>
<td>9-10 year-olds</td>
<td>Quasi-experimental</td>
<td>10 weeks</td>
<td>Computer was required to deliver the intervention.</td>
<td>Netherlands</td>
<td>Similar to the study titles above.</td>
<td>Increase was greater for the experimental group.</td>
<td>Log books and questionnaires to measure the intervention.</td>
</tr>
<tr>
<td>Author(s) and publication year</td>
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<tr>
<td>Huang, Su, Yang &amp; Liou (2016)</td>
<td>A collaborative digital pen learning approach to improving students’ achievement and motivation in mathematics courses.</td>
<td>Technology for engagement</td>
<td>This study assessed the impact of collaborative learning instruction using a digital pen learning system. Children in the experimental group A were divided into small groups of 4-5 for problem-based learning with the digital pen technology. Children in experimental group B used the digital pen in a traditional “lecture” based classroom. A control group was also recruited, this group experienced instruction using traditional pen and paper tasks.</td>
<td>10-11 year-olds</td>
<td>Quasi-experimental</td>
<td>1-2 weeks, 40-50 minutes per student</td>
<td>Children’s mathematics skills were assessed on mathematics knowledge using a teacher generated test. Additional 5 open questions were added to assess problem solving. Children’s learning motivation and attitudes to learning were also assessed using previously used questionnaires.</td>
<td>Pretreatment scores indicated that Experimental Group A had significantly higher posttest scores than Experimental Group B. Experimental Group B also had significantly higher scores than the Control Group. No group differences were observed in learning motivation and attitudes.</td>
<td>Taiwan</td>
<td>Digital pen hardware and software were required. Teacher developed worksheets were also provided.</td>
</tr>
<tr>
<td>Olkun, Smith &amp; Altun (2005)</td>
<td>Computers and 2D geometric learning of Turkish fourth and fifth graders.</td>
<td>Technology for engagement</td>
<td>Test the effect of computerised training on geometry learning. Children in the experimental group completed computerised 2D tangram problems. The control group was business as usual.</td>
<td>9-11 year-olds</td>
<td>Quasi-experimental</td>
<td>80-120 minutes per student, dependent on the students need to acclimatise to the software.</td>
<td>Children’s knowledge of geometry was assessed using an author-generated test. Children in the experimental group outperformed students in the control group in their geometric test scores.</td>
<td>Turkey</td>
<td>The intervention required computerised 2D tangram problems. Computers were required to run the intervention.</td>
<td></td>
</tr>
</tbody>
</table>
Interventions to improve mathematical achievement in primary school-aged children

**Author(s) and publication year**: Pili & Aksu (2013)

**Study title**: The use of computer-assisted instruction on achievement attitudes and student mathematics achievement in fourth grade students in North Cyprus.

**General focus of the study**: The study assessed the impact of computer-assisted instruction on mathematical achievement. A Quasi-experimental design was taught using traditional methods. The experimental group was taught using Frizbi Mathematics 4. Both groups received 4 hours of mathematics instruction. Following the nine-week study, the curriculum and books. The experimental group was taught using Frizbi Mathematics 4. The control group was taught using traditional textbooks and books. The experimental group then received in addition 2 hours completed Frizbi Mathematics units. The control group received additional traditional mathematics classroom instruction.

**Intervention measure(s)**: Mathematics achievement was assessed using an author-generated test covering multiplication, division, and fractions. Attitudes towards mathematics was assessed using the Mathematics Attitude Scale (MAS, Askar & El-Askar, 1986) and the Computerized Aided Learning Attitude Scale (Akar, Yesil & El-Askar, 1991). 

**Outcome(s)**: Frizbi Mathematics 4 computerised software was required to deliver the intervention. Children completed 2 hours of computerised instruction per day. Children were also required to complete 4 hours of mathematics instruction in the classroom. Children were asked to complete an author-generated lesson from the time to know program.

**Country**: Cyprus

**Intervention resource requirement(s)**: Time to learn: One computer per student. Additional resources: One laptop per student. Additional materials: Teacher-given practice

---

**Author(s) and publication year**: Roxan & Beck-Net (2012)

**Study title**: Interacting digital content and one-to-one laptop environment in teaching mathematics: Lessons from the time to learn program.

**General focus of the study**: This study investigated the impact of computer-assisted one-on-one training on mathematics learning. The intervention included tailored learning, practice environments and games. Control schools were practice as usual.

**Intervention measure(s)**: Achievement was assessed using the Math Texas Assessment of Knowledge and Skills test. Improvement in unexcused absences were also reported in the experimental group compared to the control. Children were asked to complete an author-generated lesson on learning motivation and attitudes towards computerised tools for learning.

**Outcome(s)**: Significant improvements in reading and mathematics were observed in the experimental group compared to the control. Children also reported positive effects of the computerised intervention on motivation to learn and attitudes towards computerised tools for learning.

**Country**: USA

**Intervention resource requirement(s)**: The use of the Time to Learn Program software and laptops to access the software. Additional resources: One computer per student for practitioners. Additional materials: Teacher-given practice.

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<tr>
<td>Singer (2015)</td>
<td>The effects of iPad devices on elementary school students' Mathematics achievement and attitudes.</td>
<td>Technology for engagement</td>
<td>This study assessed the impact of iPad use on children's achievement and attitudes towards mathematics. The experimental group experienced instruction with embedded iPads. A control group received traditional instruction. The course content was identical between groups.</td>
<td>8-9 year-olds</td>
<td>Quasi-experimental</td>
<td>One academic year of 180 days</td>
<td>Children's attitudes towards mathematics were measured using the Attitudes Towards Mathematics Inventory. Mathematics achievement was assessed using Pearson SuccessNet benchmarking tool, which is aligned with the school curriculum.</td>
<td>There were no group differences in achievement or attitudes, although teachers qualitatively reported increased engagement, attitudes and productivity.</td>
<td>USA</td>
<td>iPads were required to deliver this intervention.</td>
</tr>
<tr>
<td>Yi &amp; Eu (2016)</td>
<td>Effect of using Logo on pupils' learning in two-dimensional shapes.</td>
<td>Technology for engagement</td>
<td>This study assessed the use of the software program Logo on children's understanding of 2D shapes. Children were assigned to the experimental group (taught through Logo) or a business as usual control group.</td>
<td>10-11 year-olds</td>
<td>Quasi-experimental</td>
<td>2 weeks</td>
<td>Achievement in geometry was measured using a non-identified test. Perception towards Logo was measured using a questionnaire.</td>
<td>Performance in the experimental group was significantly better than the control group at post-test. Children also reported having positive perceptions of Logo.</td>
<td>Malaysia</td>
<td>Logo software and computers are required to deliver the intervention. A Logo turtle that could be programmed was also required.</td>
</tr>
<tr>
<td>Betsch &amp; Quittenbaum (2015)</td>
<td>On the Robustness of the Quizzing Effect under Real Teaching Conditions.</td>
<td>Delivery context</td>
<td>This study assessed the impact of scripted direct instruction on children's learning about symmetry. The restudying group read out answers to questions. The quizzing group recalled the answer and were given the correct feedback if incorrect.</td>
<td>9 year-olds</td>
<td>RCT</td>
<td>One 90 minute lesson</td>
<td>Geometry knowledge was assessed using an author generated geometry test, based on questions from textbooks.</td>
<td>The restudying group displayed enhanced performance at immediate follow-up. The quizzing group displayed superior performance at 6 weeks follow-up.</td>
<td>Germany</td>
<td>Script for teaching symmetry based on the school curriculum, symmetry problems—both author generated.</td>
</tr>
</tbody>
</table>
## A Systematic Review

### Interventions to improve mathematical achievement in primary school-aged children

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<tbody>
<tr>
<td>Casey, Erkut, Ceder &amp; Young (2008)</td>
<td>Use of a storytelling context to improve girls’ and boys’ geometry skills in kindergarten</td>
<td>This study aimed to assess the effectiveness of storytelling contexts to improve children’s geometry skills. There were two main sections: (1) Investigated the impact of a story context that focused on part-whole relations in comparison to a control group who received regular mathematics instruction, (2) Compared a story telling context to teach geometry versus traditional instruction on geometry.</td>
<td>Delivery context</td>
<td>5-6 year-olds</td>
<td>RCT</td>
<td>2 days x 20 min session</td>
<td>For Study 1 learning was assessed through tasks measured both near and far from geometry instruction; for transfer tasks measured both near and novel geometry pieces as in the intervention and novel paper-cut pieces respectively. A modified Kaufman Assessment Battery for Children (K-ABC) Triangles subtest was used to assess near transfer. Far transfer was assessed using a Tangram task (Schiro, 2000). Study 1 indicated that the intervention improved girls’, but not boys, performance on both near and far transfer tasks. Boys’ performance increased independent of group membership. There was no effect on far transfer tasks. Study 2 revealed that children in the story telling group improved in both near and far transfer tasks in comparison to the traditional geometry instruction group.</td>
<td>USA</td>
<td>Activity focused “Tan and the Shape Changer” and “Round the Rug Math: Adventures in Problem Solving” books, 2D and 3D shapes.</td>
<td></td>
</tr>
<tr>
<td>Gurbuz, Catligou, Birgin &amp; Erdem (2010)</td>
<td>An Investigation of Fifth Grade Students’ Conceptual Development of Probability through Activity Based Instruction: A Quasi-Experimental Study.</td>
<td>This study assessed the impact of group discussions on children’s learning. Children engaged in group discussions that questioned problem solving processes with the aim to construct knowledge compared to control children who were taught by a teacher in a traditional, didactic manner. A control group was also assessed.</td>
<td>Delivery context</td>
<td>10-11 year-olds</td>
<td>RCT</td>
<td>4 teaching hours</td>
<td>An author generated Conceptual Development Test tested sample space, probability comparisons and probability of an event reasoning skills. Higher conceptual scores at post-test were observed for all measures the experimental group than the control group.</td>
<td>Turkey</td>
<td>Probability problems-source unclear.</td>
<td></td>
</tr>
</tbody>
</table>
Interventions to improve mathematical achievement in primary school-aged children

**Author(s) and publication year:**
- Hugger (2012)
- Kocabas (2009)
- McFadden, McPherson, Doolan, Blyth & Teacher (2015a)

**Study title:**
- Evaluating the effects of Frictionless Learning Strategies (FALS) in mathematics, focusing on anxiety treatment on achievement in third grade students.
- Using songs in mathematics instruction: From pilot application.
- Physically Active Maths: Assessing the efficacy of teaching academic lessons through physical activity.

**General focus of the study:**
- General Academic
- General Country
- Songs with Teachers received 2 years: 22

**Country:**
- USA
- Turkey
- Netherlands

**Intervention summary:**
- The PAL intervention lasted for 12 weeks, children completed two 30 minute sessions per week. The relaxation intervention lasted 5 minutes of relaxation activities combined with a timed 25 minute mathematics intervention per session. The PALS and relaxation session lasted the same amount of time in the other conditions. The control group completed supplementary mathematics activities.
- Children in the intervention group experienced physically active lessons, children in the control group experienced practice as usual.
- Assessing the efficacy of teaching academic lessons through physical activity.

**Age Group:**
- 8-9 year-olds
- 8-9 year-olds
- 7-9 year-olds

**Research method:**
- RCT
- RCT
- RCT

**Intensity:**
- The PAL intervention lasted for 12 weeks, children completed two 30 minute sessions per week. The relaxation intervention lasted 5 minutes of relaxation activities combined with a timed 25 minute mathematics intervention per session. The PALS and relaxation session lasted the same amount of time in the other conditions. The control group completed supplementary mathematics activities.
- Children in the intervention group experienced physically active lessons, children in the control group experienced practice as usual.
- Assessing the efficacy of teaching academic lessons through physical activity.

**Intervention measure(s):**
- Mathematics computation scores were measured using the AIMSweb Curriculum–Curriculum–Curriculum–Curriculum (MCWWP) and anxiety was assessed using the Revised Children’s Manifest Anxiety Scale Second Edition (RCMAS-2).
- Children in the intervention group experienced physically active lessons, children in the control group experienced practice as usual.
- Assessing the efficacy of teaching academic lessons through physical activity.

**Outcome(s):**
- There were no group differences in post-test mathematics computation scores. There were significant group differences in anxiety scores.
- Teachers received training on the intervention techniques (lasting 1.2 hours). The PAL training also involved a manual and worksheets. The relaxation training worksheets were provided with a manual and command cards.
- Participants were assessed using two scales (1) Anxiety towards Mathematics (M-COMP) and (2) the Scale of Multiple Intelligences (Kocabas, 2007).
- The participant group displayed increased performance in the spreaded outcome measure compared to the control group after 2 years. Intervention participants also displayed significantly more improvement in mathematical achievement than the other participants after 2 and 1 years.

**Resource(s):**
- A Systematic Review: Interventions to improve mathematical achievement in primary school-aged children

**Additional notes:**
- Results indicated that participants in the intervention group displayed increased performance in the spreaded outcome measure compared to the control group after 2 years. Intervention participants also displayed significantly more improvement in mathematical achievement than the other participants after 2 and 1 years.

**Other details:**
- Participants were assessed using two scales (1) Anxiety towards Mathematics (M-COMP) and (2) the Scale of Multiple Intelligences (Kocabas, 2007).
- The experimental groups' positive attitude towards mathematics increased substantially more than the control group's. These differences resulted in significant improvements in mathematics achievement.
## A Systematic Review of Interventions to improve mathematical achievement in primary school-aged children

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</tr>
</thead>
<tbody>
<tr>
<td>Ruiter, Loyens &amp; Paas (2015)</td>
<td>Watch your step children! Learning two-digit numbers through mirror-based observation of self-initiated body movements.</td>
<td>Delivery context</td>
<td>Assessing the efficacy of teaching double-digit numbers through movement on a number line. Some participants were assigned to a group in which they observed their own behaviour in a mirror. Control participants were asked to construct double-digit numbers on a ruler with pencil and paper. In a second control children were asked to view a ruler across a room, verbally construct the double-digit number and then walk to the point on the ruler.</td>
<td>7-8 year-olds</td>
<td>RCT</td>
<td>One session</td>
<td>Mathematics performance was assessed using an intervention called &quot;Number Building Exercises&quot; test that assessed participants' ability to build double-digit numbers. Participants were also asked their opinion on the intervention and their views on the tasks.</td>
<td>Children in movement conditions were associated with higher mathematics test performance. There was no difference between the mirror and non-mirror movement group in terms of mathematics outcome. There were no group differences in children's opinions of the interventions.</td>
<td>Netherlands</td>
<td>Large floor ruler</td>
</tr>
<tr>
<td>van den Heuvel-Panhuizen, Elia &amp; Robitzch (2016)</td>
<td>Effects of reading picture books on kindergartners’ mathematics performance.</td>
<td>Delivery context</td>
<td>This study assessed the impact of delivery of mathematical content through picture story books on mathematical learning. Teachers were provided with scripts to guide their questioning with participants, these activities were completed over and above traditional mathematics instruction. Control children experienced traditional classroom teaching only.</td>
<td>8-9 years-old</td>
<td>RCT</td>
<td>Academic term</td>
<td>Participants were assessed using two scales (1) Attitude towards Mathematics (Bielaczyc, 1999) and (2) the Scale of Multiple Intelligences (Kormi, 2007). The experimental group’s positive attitude towards mathematics increased more substantially than the control group. There were no significant improvements in mathematics achievement.</td>
<td>Turkey</td>
<td>Songs with mathematical content recorded to CD, author-generated.</td>
<td></td>
</tr>
</tbody>
</table>
Using a computerized intervention to teach primary school-aged children mathematics.

**Spivak & Frese (2009)**
**Evaluation of an innovative mathematics program in terms of classroom environment, student attitudes, and conceptual development.**

**Table:**

<table>
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<tr>
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<tr>
<td>Fraser (2005)</td>
<td>Using Country General Intervention As this is a General Country G-Math peer Intervention</td>
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</table>

The study assessed the impact of the Class Banking System (CBS) on mathematical learning. This system assists students in solving mathematical problems using computer-aided approaches through an innovative program, focusing on conceptual development through collaboration with classmates. Children were assigned to either an experimental or a control group. The intervention lasted one academic year. The classroom environment was measured using the Individualised Classroom Environment Questionnaire and the Classroom Environment Survey. Attitudes toward mathematics were measured using the Test of Mathematics Anxiety Related Attitudes. An author-generated concept map was also administered. This measured children's knowledge of geometry, algebra, etc. Additional case studies were also completed. Change in environment scores were significant for both groups of students. Changes associated with the change was generally larger for the experimental group compared to the control group. The control group worked 20% less than the experimental group. Changes in environment were reported. As this is a change in approach in teaching no additional resources are required. USA

**Nuss (2012)**
**Using synchronous peer tutoring system to promote elementary students’ learning in mathematics.**

**Table:**

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<tbody>
<tr>
<td></td>
<td>Using a computerized intervention to teach primary school-aged children mathematics.</td>
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</table>

This study assessed the effectiveness of a peer tutoring system on mathematical learning. Children were either assigned to an experimental group who experienced peer tutoring or a control group in the peer tutoring system allowing children to receive feedback, peer rating, and rewards. Two school semesters with three 40 minute mathematics sessions per week. The first session per week both the control and experimental group received whole class instruction. The second session, students in the control group received whole class instruction. In the third session the experimental group worked online in pairs. The effect size of subscales. The experimental group displayed significantly greater increase in self-concept and intrinsic goal orientation when compared to the control group. USA

**Note:** The experimental group significantly greater gains in mathematical achievement compared to the control group. The experimental group also displayed significantly greater increase in self-concept and intrinsic goal orientation when compared to the control group. The experimental group was also administered. And good motivation was also assessed using the intrinsic goal orientation items from the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993). A mathematical reasoning test (Kramarski & Zoldan, 2008) was used to assess problem solving during the tutoring session. A web-based assessment tool was used to measure children’s achievement. The questionnaire was also assessed using the mathematical feedback. The Self Concept Scale for Children was also administered. And good motivation was also assessed using the intrinsic goal orientation items from the Motivated Strategies for Learning Questionnaire (Pintrich et al., 1993).
A Systematic Review of Interventions to Improve Mathematical Achievement in Primary School-Aged Children

### Author(s) and Publication Year
- Erdogdu & Baran (2009, Turkey).
- Visscher, Doolaard, Bosker, de Greef, Hartmen, Wusma, Mullender, 

### Study Title
- Improving academic performance of school-aged children by physical activity in class: classroom experiment (age 10-15 years).
- An academic instruction to engage third-grade students in learning basic fraction concepts.

### General Focus of the Study
- Improving the effect of combining physical activity into learning activities. The study assessed the effectiveness of combining physical activity into learning activities. The control group engaged in traditional lessons, while the experimental group engaged in physically active lessons.
- Assessed the effect of mathematics teaching through drama on the numerical ability of six-year-old children.
- Engaging third-grade students in learning basic fraction concepts.

### Intervention Summary
- The intervention was delivered over a period of one year. Each lesson consisted of 30 minutes of physical activity and then 10-15 minutes on language problems. The intervention consisted of 3 sessions a week for 21 weeks.
- Children were assigned to an experimental group in which mathematics was taught through drama (such as role-play), through counting, mapping etc. A placebo control group engaged in activities that were not specifically tailored to develop mathematics skills. A control group attended class as usual.
- Assessed the effect of a music intervention on mathematical achievement, specifically on note identification, rhythm and subtracting notes. A control group was also assessed.

### Country
- Netherlands.
- Turkey.
- USA.

### Research Methods
- Quasi-experimental.
- Quasi-experimental.
- Quasi-experimental.

### Interventions Resource Requirement(s)
- Specialist teachers delivered the intervention. An interactive whiteboard was used in this intervention. Lesson material such as a manual and lesson content.
- A music intervention focused specifically on musical notes. A control group engaged in traditional lessons. The control group engaged in traditional lessons.
- Music lessons were taught through drama (such as role-play), focusing on note identification, counting, mapping etc. A placebo control group engaged in activities that were not specifically tailored to develop mathematics skills. A control group attended class as usual.

### Outcome Measure(s)
- Mathematics ability was measured using the Tempo-Test (1 Minute test).
- Reading ability was assessed via the Tempo-Test (1 Minute test).
- Reading ability was assessed with the Minuut-Test. Mathematics ability was assessed with the Form and the Information General Test.

### Outcome(s)
- There was no significant group difference for reading skills.
- There was a significant group difference for mathematical achievement.
- Children in the experimental group outperformed the control group.

### Summary
- The intervention was effective in improving academic performance of school-aged children by combining physical activity into learning activities. The study assessed the effectiveness of combining physical activity into learning activities. The control group engaged in traditional lessons, while the experimental group engaged in physically active lessons. Mathematics ability was measured using the Tempo-Test (1 Minute test). Reading ability was assessed with the Minuut-Test. Mathematics ability was assessed with the Form and the Information General Test. There was no significant group difference for reading skills. There was a significant group difference for mathematical achievement. Children in the experimental group outperformed the control group. There was no significant group difference for reading skills. There was a significant group difference for mathematical achievement. Children in the experimental group outperformed the control group. There was no significant group difference for reading skills. There was a significant group difference for mathematical achievement. Children in the experimental group outperformed the control group.
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<tr>
<td>Cakiroglu &amp; Sarioglu (2012)</td>
<td>The effects of using drawings in developing young children’s mental arithmetic word problem solving</td>
<td>Intervention with handwriting Hungarian students.</td>
<td>Delivery context</td>
<td>8-9 year-olds</td>
<td>Quasi-experimental</td>
<td>20 lessons (did not exceed 45 minutes per session over 3 weeks)</td>
<td>Author generated tasks were as follows: 1. Arithmetic skill test that covered the number topics. 2. A word problem test and a word problem test for mathematics.</td>
<td>Although performance on both the arithmetic skill and word problem test improved over the course of the intervention, there was no difference between the intervention and control group in terms of their post-test performance.</td>
<td>Hungary.</td>
<td>Teacher training and support throughout the intervention.</td>
</tr>
<tr>
<td>Huang, Tseng &amp; Shadiev (2012)</td>
<td>Making instruction and learning responsive to diverse students’ progress: Group-administered dynamic assessment in teaching mathematics</td>
<td>Intervention</td>
<td>Delivery context</td>
<td>9-10 year-olds</td>
<td>Quasi-experimental</td>
<td>There were four units and each unit consisted of 10 lessons across a two-week period.</td>
<td>Outcomes were assessed via a group-administered dynamic post-test or the same test, but with filler materials. Teachers were assessed via geometry, measurement, and equivalent fraction tests. These tests had been used in previous studies by the authors.</td>
<td>USA.</td>
<td>Teachers received two 40’s worth of training prior to the intervention.</td>
<td></td>
</tr>
<tr>
<td>Szitanyi, Csikos &amp; Sophienbaum (2011)</td>
<td>A self-regulated flipped classroom approach to improve students’ learning performance in mathematics course</td>
<td>Intervention</td>
<td>Delivery context</td>
<td>10-11 year-olds</td>
<td>Quasi-experimental</td>
<td>The study assessed the effectiveness of a flipped classroom approach. Children were assigned to a self-regulated experimental group or a traditional flipped classroom control group. Classroom children in the experimental group were asked to set their own learning goals.</td>
<td>Mathematics learning was assessed through a performance test developed by three teachers. Selfefficacy and self-regulation were assessed using a questionnaire.</td>
<td>The experimental group was provided with handout and quiz materials through an online system.</td>
<td>Taiwan.</td>
<td>Students were provided with handout and quiz materials through an online system.</td>
</tr>
</tbody>
</table>
Relevant studies to improve mathematical achievement:


Interventions to improve mathematical achievement in primary school-aged children


Obersteiner, A., Reiss, K., & Ufer, S. (2013). How training on mental addition of representational number can enhance first-grade students’ basic number processing and arithmetic skills. Learning and Instruction, 23, 125-133.


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Interventions to improve mathematical achievement in primary school-aged children


Interventions to improve mathematical achievement in primary school children


The long-term cost of numeracy difficulties. United Kingdom: Department for Education. 2013. 597.
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