Interventions in Solving Equations for Students with Mathematics Learning Disabilities
A Systematic Literature Review

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ABSTRACT

Approximately 5 to 14% of school age children are affected by mathematics learning disabilities. With the implementation of inclusion, many of these children are now being educated in the regular education classroom setting and may require additional support to be successful in algebra. Therefore, teachers need to know what interventions are available to them to facilitate the algebraic learning of students with mathematics learning disabilities. This systematic literature review aims to identify, and critically analyze, interventions that could be used when teaching algebra to these students. The five included articles focused on interventions that can be used in algebra, specifically when solving equations. In the analysis of the five studies two types of interventions emerged: the concrete-representational-abstract model and graphic organizers. The concrete-representational-abstract model seems to show it can be used successfully in a variety of scenarios involving solving equations. The use of graphic organizers also seems to be helpful when teaching higher-level algebra content that may be difficult to represent concretely. This review discovered many practical implications for teachers. Namely, that the concrete-representational-abstract model of intervention is easy to implement, effective over short periods of time and appears to positively influence the achievement of all students in an inclusive classroom setting. The graphic organizer showed similar results in that it is easy to implement and appears to improve all students’ learning. This review provided a good starting point for teachers to identify interventions that could be useful in algebra; however, more research still needs to be done. Future research is suggested in inclusive classroom settings where the general education teacher is the instructor and also on higher-level algebra concepts.

Keywords: Algebra, Concrete-Representational-Abstract, Dyscalculia, Explicit Inquiry Routine, Graphic Organizers, Inclusion, Inclusive Classroom Setting, Interventions, Mathematics Learning Disabilities
# Table of Contents

1 Introduction .........................................................................................................................1

1.1 Mathematics learning disabilities .................................................................................1

1.2 Inclusive classroom setting .........................................................................................2

1.3 Interventions ..................................................................................................................3

1.4 Vygotsky’s theory of cognitive development ...............................................................3

1.5 Rationale for this study .................................................................................................4

1.6 Aim ..................................................................................................................................4

2 Method ...............................................................................................................................5

2.1 Procedure .......................................................................................................................5

2.1.1 Literature search .......................................................................................................5

2.1.2 Inclusion and exclusion criteria ..............................................................................6

2.2 Peer-review process ......................................................................................................6

2.3 Data extraction ..............................................................................................................7

2.3.1 Abstract screening ....................................................................................................7

2.3.2 Full-text screening ...................................................................................................8

2.4 Quality assessment .......................................................................................................9

2.5 Analysis ..........................................................................................................................11

3 Results ...............................................................................................................................12

3.1 Search results ..............................................................................................................12

3.2 Description of MLD ......................................................................................................13

3.3 Interventions ................................................................................................................14

3.3.1 CRA model ..............................................................................................................14

3.3.2 Graphic organizers ..................................................................................................16

3.4 Implementation of interventions ..................................................................................16

3.5 Outcomes of interventions ..........................................................................................18

4 Discussion .........................................................................................................................23
I Introduction

A lot of focus has been put on mathematics concepts and interventions in the elementary school setting (Baker, Gersten, & Lee, 2016; Doabler, Fien, Nelson-Walker, & Baker, 2012; Foegen, 2008a; Kroesbergen & Van Luit, 2003; Mastropieri & Scruggs, 2016; Satsangi & Bouck, 2015). Early intervention aims to provide help to students who are at risk of negative mathematics outcomes before they develop severe deficits and to prepare them for the increasingly abstract mathematics they may encounter in later years (Fuchs et al., 2008; Maccini & Hughes, 2000). By developing students’ prealgebraic thinking skills they would ideally become more capable of success later in algebra. However, there is a large gap in the thinking required in arithmetic and in algebra (Dougherty, Bryant, Bryant, Darrough, Pfannenstiel, et al., 2015; Jitendra et al., 2009; Kroesbergen & Van Luit, 2003; Witzel, Smith, & Brownell, 2001). This poses a problem for all students, but especially for those students with mathematics learning disabilities (MLD), who have been shown to achieve at a lower rate than students without learning disabilities (Agrawal & Morin, 2016; Dougherty, Bryant, Bryant, Darrough, & Pfannenstiel, 2015; Foegen, 2008b; Hunt & Vasquez III, 2014; Kortering, deBettencourt, & Braziel, 2005; Maccini & Hughes, 2000; Satsangi & Bouck, 2015).

In the United States, many states have now included passing algebra as a requirement for high school graduation (Foegen, 2008a; Maccini & Hughes, 2000). Due to the implementation of inclusion, students with MLD are increasingly being taught in inclusive classroom settings (Dougherty, Bryant, Bryant, Darrough, Pfannenstiel, et al., 2015; Mastropieri & Scruggs, 2016). The new graduation requirements and the added impact of inclusive classroom settings have resulted in extra pressure to close the gap in learning for students with MLD (Foegen, 2008a; Hunt & Vasquez III, 2014; Kortering et al., 2005). This has created a demand for more intervention studies with a specific focus on algebra. Algebra will be defined, for this review, as the concept of variability and how it is used in algebraic expressions, formulae and equations and also the use of methods to solve equations (Maccini & Hughes, 2000; Skolverket, 2011).

1.1 Mathematics learning disabilities

Dyscalculia is a term used to cover a wide range of mathematics learning disabilities (von Aster & Shalev, 2007). Dyscalculia can be viewed as a negative term to describe students with MLD. It has been discussed by Mazzocco, Feigenson and Halberda (2011) that the terms dyscalculia and MLD are synonymous and therefore, the term MLD can be used in place of dyscalculia. Due to this, the term dyscalculia will not be used for the remainder of this study; instead, the term MLD will be used.

MLD affects approximately 5 to 14% of school age children (Geary, 2004; Kroesbergen & Van Luit, 2003; Mazzocco et al., 2011; Shin & Bryant, 2015). These children are able to achieve age appropriate gains in other areas, but still struggle in mathematics despite being presented with enough learning opportunities (Shalev, Manor, & Gross-Tsur, 2007; von Aster & Shalev, 2007). However, it can be difficult to
ascertain if the poor achievement in mathematics is due to a cognitive disability or if it is due to inadequate instruction (Geary, 2004; Kroesbergen & Van Luit, 2003). Although, most often, MLD appears as counting or other mathematics difficulties, problems learning basic mathematics facts or having problems with “number sense” (Geary, 2004; Kroesbergen & Van Luit, 2003; Shin & Bryant, 2015; Wilson, 2008). The term “number sense” encompasses the abilities to represent and manipulate, both verbally and non-verbally, numerical quantities on a spatially oriented, mental number line (Geary, Hamson, & Hoard, 2000; von Aster & Shalev, 2007). Students with MLD often have difficulties with visual-spatial relationships and these interruptions make it difficult for students to develop number sense, sequence numbers and understand the concept of quantity (Geary, 2004; von Aster & Shalev, 2007). Due to the fact that early number concepts often rely on the ability to sequence numbers and visualize quantities, students with MLD do not develop a strong conceptual base on which they are able to build more operational and procedural skills (Fleischner & Manheimer, 1997). Mathematics concepts are cycled through over and over as a student moves through school; however, the way the concepts are used becomes more and more abstract (Sameroff, 2010). A firm grasp of numbers and basic mathematical concepts benefits students and aids in the development of later, more abstract mathematical concepts, such as, fractions or algebra (Kroesbergen & Van Luit, 2003; Mazzocco, Myers, Lewis, Hanich, & Murphy, 2013).

Even though MLD is fairly common in school age children, it is difficult to diagnose (Geary, 2004). There is not a specific test that is used for diagnosis. Therefore, the most common way students are diagnosed with MLD is through the reliance of standardized test scores in combination with measures of intelligence (IQ) (Geary, 2004). If students have a score lower than the 25th percentile on the mathematics component of a standardized test, but show a low-average or higher IQ score than they are typically diagnosed as having MLD (Geary et al., 2000; Geary, 2004). This fits with the concept that students with MLD are able to make appropriate gains in other areas, but still struggle in mathematics (Shalev, Manor, & Gross-Tsur, 2007; von Aster & Shalev, 2007).

1.2 Inclusive classroom setting

Due to the implementation of inclusion, inclusive classroom settings are becoming a reality for teachers and students. An inclusive classroom setting aims to incorporate students with special educational needs and typically developing students (Mitchell, 2014). Inclusive classroom settings require that schools are transformed to meet the needs of all children, including those with disabilities, and that entails changes on several environmental levels (Falkmer, Oehlers, Granlund, & Falkmer, 2015; UNESCO, 2005).

Since the UN Convention on the Rights of Persons with Disabilities in 2006, students with disabilities, including MLD, are increasingly being included within the general education system (Mastropieri & Scruggs, 2016; UN, 2006, Art. 24). With the signing of the Incheon Declaration at the World Education Forum in 2015, a continued emphasis on inclusion has been recognized (UNESCO, 2015). Therefore, the focus on inclusion will only be emphasized in the years to come and more inclusive settings will be real-
ized in practice. However, this increased focus on inclusive classroom settings is not reflected in teacher education programs. This lack of teacher training results in a major barrier to inclusion (Bornman & Rose, 2010). Part of teaching in an inclusive classroom setting is ensuring that all students are learning and capable of learning, even if that means providing support or accommodations (Mitchell, 2014; Norwich & Lewis, 2007). If teachers are expected to ensure learning in inclusive classroom settings they need to be instructed in research-based practices that allow students with disabilities more time to participate in the classroom (Adair, Ullenhag, Keen, Granlund, & Imms, 2015; Falkmer et al., 2015; Hwang, Granlund, Liao, & Kang, 2013; Mitchell, 2014; Montague, Krawec, Enders, & Dietz, 2014). One way to support students is through the use of interventions.

### 1.3 Interventions

Interventions are planned actions that are used to enhance the attainment of skills and remove barriers (Norwich & Lewis, 2007). Students with learning disabilities, educated in inclusive classroom settings, may need some type of intervention to be able to attain positive mathematics outcomes. However, teachers not only need to know what interventions are available to them, but they need to be able to differentiate the interventions based on the individual needs of students (Mazzocco et al., 2011). This can be done by identifying the specific needs of their students, developing instructional plans using the available interventions to individually address those needs, and then changing their instruction strategies to best meet the needs of each student in the classroom (Fleury et al., 2014; Strain, Schwartz, & Barton, 2012).

Explicit inquiry routine (EIR) is an intervention that has been researched extensively in special education and shown to be effective for teaching students with learning disabilities (Agrawal & Morin, 2016; Baker et al., 2016; Doabler et al., 2012; Gersten et al., 2009; Kroesbergen & Van Luit, 2003; Strickland & Maccini, 2010). EIR is a way to systematically teach students through the use of an advanced organizer, teacher modeling, guided practice, problem solving practice, independent practice and feedback (Agrawal & Morin, 2016; Strickland & Maccini, 2010). The instruction begins with the use of an advanced organizer that states the learning objectives and connects them to real-life situations (Kim, Wang, & Michaels, 2016). The next steps are teacher modeling and guided practice, critical to these steps is the selection of meaningful examples (Baker et al., 2016; Doabler et al., 2012; Kim et al., 2016). As the examples a teacher chooses influences the ability of students to generalize rules or schemas they can then apply to other types of problems (Kim et al., 2016). Then, students practice independently and receive feedback on their work.

### 1.4 Vygotsky’s theory of cognitive development

Vygotsky’s theory of cognitive development is based on the assumption that through a child’s interaction, with the adults in the child’s environment, a child is able to gain more advanced forms of thinking (Gredler, 2012). Vygotsky noted there are two cognitive processes that are important to develop thinking. “They are the extent of the student’s (a) conscious awareness of his or her own thinking and (b) under-
standing the psychological nature of the task” (Gredler, 2012, p. 125). Therefore, teachers need to ensure students are aware of their thinking and fully understand the task they are asked to do.

The zone of proximal development is used in Vygotsky’s theory to identify an important moment in the process of child development (Kozulin, 2003). The zone of proximal development is where students are able to imitate an activity with the help of an adult, or more competent child (Kozulin, 2003). Children are not able to perform the activities independently, but can be taught through direction, cooperation or leading questions (Kozulin, 2003). Teachers can use the zone of proximal development to identify where students’ intellectual functions are maturing and then teach new concepts within the zone of proximal development (Gredler, 2012).

One way to help students learn within their zone of proximal development is through the use of scaffolding. The teacher, or more competent child, use scaffolds to support and facilitate the learner. When using scaffolding, the activities are within the learner’s zone of proximal development, that is, they lie just beyond what the learner is able to accomplish on their own (Olson & Pratt, 2000). As the student develops in their thinking the scaffolds are gradually removed and the learner is able to accomplish the task, or activity, on their own.

1.5 Rationale for this study

Students with MLD are increasingly being taught in inclusive classroom settings. Teachers are often not trained in how to help students with MLD. Therefore, mathematics teachers need to know what interventions are available to them to facilitate the algebraic learning of students with MLD. In addition, research in the field of MLD is at least thirty years behind that of similar learning disabilities, like dyslexia (Geary et al., 2000; Wilson, 2008). Impecoven-Lind and Foegen (2010) noted research on algebra was very limited, in two reviews of interventions for secondary students with learning disabilities, only three studies were found that addressed algebra. The research base is likely to have grown and it is hoped, this systematic literature review will yield more results. The results will inform teachers of interventions available when teaching algebra to students with MLD.

1.6 Aim

The aim of this systematic literature review was to identify, and critically analyze, the interventions general education teachers can use, in inclusive classroom settings, for students with MLD when teaching algebra. Answering the following research questions will fulfill the aim of this study.

- What are the descriptions of MLD used in these studies?
- What interventions have been studied for students with MLD in algebra?
- What were the outcomes from the interventions on the algebraic learning of students with MLD?
2 **Method**

This study presents a systematic review of the literature using a database keyword search. The studies were refined and selected using inclusion and exclusion criteria on the abstract and the full-text level (Lyngø, Donohue, Bornman, Granlund, & Huus, 2013).

2.1 **Procedure**

The search procedure consisted of a database electronic search and a hand search to find all literature relevant to the aim of this study.

2.1.1 **Literature search**

A keyword search was performed using the ERIC, Academic Search Elite, Web of Science, JSTOR, Science Direct and SCOPUS databases. These databases were chosen because they are the most prominent in educational research. The search was done in March 2016. The search terms “(learning disabilities” OR “writing difficulties” OR “learning problems” OR “math* learning disability” OR dyscalculia) AND algebra AND intervent*” were used. Truncations were used for some search terms to capture a variety of similar terms; for example “math* learning disability” was used to find math learning disability or mathematics learning disability. Some of the search terms were found through the thesaurus of the database and then combined and used in every database search. For example, the search term “writing difficulties” was a thesaurus term for dyscalculia in the ERIC database and was combined in the search string and used in every database search. This resulted in irrelevant results in some databases, but ensured all relevant articles were found in every database. For instance, in JSTOR, the search term “writing difficulties” caused many articles that discussed learning disabilities in English rather than Mathematics to be included in the results. However, the total number of hits was not overwhelming and the irrelevant articles were just discarded and not used for full-text review.

Additional search criteria were applied within in each database to help locate relevant articles based on publication type, publication date and language. Only full-length and scientific, or academic, journal articles were included and other types of literature: books, book chapters, conference papers, theses and other literature were excluded. The limitation chosen to get the research available within the past twenty years was that the article had to have a publication date between January 1996 and January 2016. Only articles from peer-reviewed journals and written in English were selected for further evaluation. This resulted in 285 total articles. Thirty-four articles were found to be duplicates. Then, inclusion and exclusion were applied, at the abstract level, to the remaining 251 articles. For a complete description of this process see the flowchart in Appendix A.

After articles were reviewed at the full-text level and included, the references were hand searched. Four additional articles were found and reviewed at the full-text level. After the full-text screening process it was noticed that three of the articles included in this review came from the journal *Learning Disabilities*
Research and Practice. This journal was hand searched to ensure no relevant articles had been missed. The journal was located in the Wiley database and the term “algebra” was used to search within the journal. All hits were then screened at the title and abstract level using the inclusion and exclusion criteria. However, no additional articles were found that met the criteria for this review.

During the peer-review process of this thesis a second reviewer identified one article and it was included for review at the full-text level.

2.1.2 Inclusion and exclusion criteria

At the abstract level, the inclusion criteria included articles (1) that described children with mathematics learning disabilities (2) with children between six and eighteen years old (3) that specifically focused on algebra and (4) that were empirical research studies. The exclusion criteria were the article (1) did not include a description of a mathematics learning disability (2) did not describe classroom-based interventions (3) did not specifically focus on algebra and (4) was a review or case study. See Table 1 for inclusion and exclusion criteria. After applying the inclusion and exclusion criteria at the abstract level, articles were then evaluated at the full-text level.

Table 1

| Inclusion and Exclusion Criteria for Search and Abstract Level Screening |
|--------------------------|--------------------------|
| **Search Criteria**      | **Exclusion Criteria**   |
| Publication type         | - Books, book chapters, conference papers, theses or other literature |
| - Articles               |                          |
| - Published in English   |                          |
| - Published between January 1996 and January 2016 |                          |
| **Abstract Criteria**    |                          |
| Population               | - Did not include any description of mathematics learning disabilities |
| - Described children with mathematics learning disabilities |                          |
| - Children between six and 18 years old |                          |
| Design                   | - Did not describe classroom-based interventions |
| - Specifically focused on algebra | - Did not specifically focus on algebra |
| - Empirical research study | - Was a review or case study |

2.2 Peer-review process

In the databases ERIC, Web of Science, SCOPUS and Academic Search Elite there were very few search results and the majority of them were duplicates found in other databases. For example, Web of Science produced only one unique article not found in the results in ERIC, and Academic Search Elite produced only one article not found in a previously searched database. However, JSTOR had the highest number of search results, unique hits and irrelevant articles. This is why JSTOR was chosen for peer-
review. A second reviewer duplicated the search using the search terms and search criteria and then went through the search results using the inclusion and exclusion criteria at the abstract level. Both the author and the second reviewer had the same number of search results, 122. After the abstract level evaluation, the second reviewer included ten articles. Of those ten, the author had not included six. Therefore, both the author and the second reviewer agreed on 116 articles out of the 122 articles found. This represents an agreement of 95%. After further discussion, both reviewers agreed five of the articles did not actually meet the criteria for the systematic review and the sixth article was agreed to be included. This makes an agreement rate of 100%. The agreement percentage was calculated by dividing the number of agreements by the total number of agreements and disagreements and multiplying by 100 (Kennedy, 2005). Some of the confusion about which articles to include and which articles to exclude came from the definition of algebra. The second reviewer is not well versed in the area of algebra and therefore included some articles that did not actually reference algebra. Four of the five articles discussed and excluded were because they did not actually discuss algebra; the fifth excluded article did not include students with MLD. The sixth article included by the second reviewer was missed by the author and included for full-text review.

A second reviewer also evaluated four articles at the full-text and data extraction level using the protocol (see Appendix B). Two articles had been excluded during the full-text analysis by the author and two articles were included in the study. The two excluded articles showed a 100% agreement rate. Both the author and the second reviewer excluded the articles for the same reasons and had identically filled in the protocol. The included articles had an 89% agreement rate. The differences found, in the full-text review and data extraction portion of the protocol, were specifically in the descriptions of the interventions and measurement tools. This could be due to the to the fact that the second reviewer has limited algebra knowledge. No changes were made to the protocol after this peer-review process.

2.3 Data extraction

Data was extracted from the articles at the abstract and full-text level through the use of a protocol (see Appendix B).

2.3.1 Abstract screening

The title and abstract screening process consisted of reading the titles and abstracts while considering the inclusion and exclusion criteria. See Table 1 for a full list of the criteria used. The protocol was used at the abstract-level to record which of the criteria was or was not fulfilled (see Appendix B). If the article failed to meet the criteria in more than one category of the inclusion or exclusion criteria it was just recorded for one. Therefore, some articles were excluded for not satisfying criteria in more than one category, but the majority of the excluded articles did not have a specific focus on MLD. The reason for this was explained above; some of the search terms used in databases were created using a thesaurus from a different database and this resulted in irrelevant hits. Some of the articles found in JSTOR did not have an abstract and instead the first three paragraphs of the introduction were read. While reading, the inclusion
and exclusion criteria were searched for, and then the article was either included or excluded for full-text review. During this process a total of 239 articles were excluded from the review process, for a detailed list of the reasons why see the flowchart in Appendix A.

2.3.2 Full-text screening

As the articles were read at the full-text level the inclusion and exclusion criteria, the aim of this study and the research questions were kept in mind. Twelve articles were included for full-text review after the abstract level screening process. After the full-text screening process, the references of the included articles were hand searched and four additional articles were reviewed at the full-text level. During the abstract peer-review process one additional article was found and included for full-text review. This resulted in a total of 17 articles reviewed at the full-text level.

At the full-text level the articles were screened using a protocol (see Appendix B). At this stage, 12 articles were excluded for various reasons (see Appendix A). During the full-text screening process articles were excluded because (1) the articles did not include classroom-based interventions, (2) the articles did not include algebra and (3) they were reviews.

Two of the articles that were excluded (Foegen, 2008b; Kortering et al., 2005) did not actually evaluate a classroom-based intervention. In the Study conducted by Foegen (2008) the use of algebra progress monitoring measures to track student learning in order to help determine when teachers may need to change instructional strategies for students experiencing difficulty were evaluated. This did not fulfill the aim of the study in that it did not identify an intervention that could be used when teaching algebra to students with learning disabilities. Kortering et al. (2005) conducted qualitative research and asked students to identify interventions they believed would be helpful for them, but none of the interventions were actually implemented.

Six articles (Dougherty, Bryant, Bryant, Darrough, & Pfannenstiel, 2015; Hunt & Vasquez III, 2014; Maccini & Hughes, 2000; Satsangi & Bouck, 2015; Xin, 2008; Yan Ping Xin, Wiles, & Lin, 2008) did not discuss algebra concepts. Four of the articles (Dougherty, Bryant, Bryant, Darrough, & Pfannenstiel, 2015; Hunt & Vasquez III, 2014; Xin, 2008; Yan Ping Xin et al., 2008) discussed algebra readiness or developing prealgebraic thinking and did not actually evaluate interventions in the area of algebra. In the study conducted by Maccini and Hughes (2000) the authors focused on the manipulation of integers; adding, subtracting, multiplying and dividing. Although, the article discussed algebra at both the abstract and full-text level the integer concepts used in the study did not meet the definition of algebra used in this review. The study by Satsangi and Bouck (2015) focused on the geometry concepts of area and perimeter.

Lastly, four of the articles (Mastropieri & Scruggs, 2016; Steele & Steele, 2015; Tricia K Strickland & Maccini, 2010; B. Witzel et al., 2001) did not evaluate the outcome of interventions using an empirical study, but rather discussed, or reviewed, what the research said about available interventions.
Three articles (Ives, 2007; Scheuermann, Deshler, & Jean, 2009; Tricia K Strickland & Maccini, 2013) were included after the full-text review even though they met one of the exclusion criteria for this search; the research was not conducted in an inclusive classroom setting. The research was conducted in a private school where all students had learning disabilities (Ives, 2007; Scheuermann et al., 2009) or it was conducted in a separate setting, outside of the classroom (Tricia K Strickland & Maccini, 2013). However, the interventions used in those studies could be used in an inclusive classroom setting. Therefore, they were in line with the aim of this study and discussed interventions available to general education teachers teaching in inclusive classrooms and were included in this study. An overview of all included articles can be found in Appendix 3.

A total of five articles were included in this systematic literature review. See Table 2 for more information about the included articles. These articles included interventions that could be used in an inclusive classroom setting to teach algebra to students with MLD. The articles were also checked for quality; however, there were so few articles that all were included for the review even if they were not of the highest quality. A complete overview of all included articles can be found in Appendix C.

Table 2

<table>
<thead>
<tr>
<th>Author, year and title of included articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Author</td>
</tr>
<tr>
<td>--------</td>
</tr>
</tbody>
</table>

2.4 Quality assessment

The quality of the articles was assessed at the full-text level with the help of the protocol (see Appendix B). The quality was evaluated using the following criteria: published in a peer-reviewed journal, study design, sample size, informed consent, how they defined mathematics learning disability, analysis method and effect sizes of the intervention. Using guidelines presented by Wells and Littell (2009), a table was created and each article was rated as high, medium or low for each of the criteria.
Table 3

Study design ratings

<table>
<thead>
<tr>
<th>Study design</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Randomized control design</td>
<td>High</td>
</tr>
<tr>
<td>Non-randomized comparison groups</td>
<td>Medium</td>
</tr>
<tr>
<td>Observational studies – case studies or single-group studies</td>
<td>Medium</td>
</tr>
<tr>
<td>Non-experimental case study</td>
<td>Low</td>
</tr>
</tbody>
</table>

If the study was published in a peer-reviewed journal it was rated as high and if it was not, it was rated as low. The study design was rated hierarchically with randomized control design being rated the highest and non-experimental case study being rated the lowest. Non-randomized comparison groups were rated below randomized control trials, but above observational studies, such as case-control or single-group studies. All study designs found between randomized control design and non-experimental case study were given the rating of medium (see Table 3).

The sample size was determined to be high, medium or low quality by looking at the number of participants and reading the limitations of the study. If there were a reasonable number of participants, when compared to similar studies, involved in the study and sample size was not listed as a limitation then it was ranked as high. If the number of participants seemed small for the study, when compared to similar studies, and it was listed as a limitation then it was ranked as low. The medium ranking was used if the study was ranked as high in one category, either sample size or limitation, and low in the other category. For informed consent, if the authors mentioned obtaining informed consent then it was ranked as high and if they did not it was ranked as low. How the authors defined the term MLD for the inclusion criteria of participants in their study was also ranked. If they included multiple variables and descriptions that encompassed areas such as IQ, diagnosis, IEP goals or others then it was ranked as high. If they only included one variable, such as diagnosis, then it was ranked as low. The study was ranked as either high, medium or low for analysis method and effect size. This ranking was made based on the description of the analysis and if an effect size was mentioned. If they study included a detailed description of analysis methods and effect sizes, it was ranked as high. A medium ranking was given if it included a detailed description of analysis methods, but no effect size. Finally, if the article did not include a detailed description of analysis methods and did not have an effect size it was ranked as low. Using the rankings from each criterion the article was then given an overall ranking of high, medium or low quality. In order to have an overall ranking of high, the study had to have a ranking of high on at least four of the criteria and no ranking of low. A table showing the quality assessment of all included articles can be found in Table 4.
### Table 4

**Quality Assessment of Included Articles**

<table>
<thead>
<tr>
<th>Author</th>
<th>Peer-reviewed journal</th>
<th>Study design</th>
<th>Sample size</th>
<th>Informed consent</th>
<th>Definition of MLD</th>
<th>Analysis method and effect sizes</th>
<th>Overall ranking</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. – Study 1</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Ives, B. – Study 2</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Scheuermann et al.</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Strickland, T. &amp; Maccini, P.</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>Witzel et al.</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>Witzel, B.</td>
<td>High</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

#### 2.5 Analysis

The abstract protocol was reviewed again at the full-text level and any additional data found during the full-text reading was added. Then, the full-text protocol was used to analyze the articles and extract data (see Appendix B). As the article was read the protocol was filled in. The article was read and searched until all aspects of the protocol were filled in or the author was sure the information could not be found.

The protocol was used to identify information about the study design and was used for quality assessment purposes as well as to extract data about the study. In addition, the protocol was used to identify the purpose and research questions of the study, any theoretical perspectives, if a specific content problem within algebra was identified, information about the intervention - how it was implemented and the scientific basis behind it, information about the measurement tools used, the results of the study, the outcome of the intervention and any conclusions and implications from the research.
3 Results

The systematic literature search, abstract screening process and full-text screening process resulted in five included articles. Data was extracted for the three research questions (1) What are the descriptions of MLD used in these studies? (2) What interventions have been studied for students with MLD in algebra? and (3) What were the outcomes on the algebraic learning of students with MLD?

3.1 Search results

After the abstract screening, 12 articles were included for review at the full-text level. During the abstract peer-reviewing process one additional article was found that was included for full-text review. After the full-text review process, the references of the included articles were hand searched for articles relevant to this study and four additional articles were found that were included for full-text review. This resulted in a total of 17 articles that were reviewed at the full-text level. During the full-text screening process articles were excluded because (1) the article did not include classroom-based interventions, (2) the article did not include algebra and (3) it was a review.

Following the systematic review process, five studies were analyzed. Of the five studies two implemented single subject designs (Scheuermann, Deshler, & Jean, 2009; Strickland & Maccini, 2013), two used a random assignment of clusters design (Witzel, Mercer, & Miller, 2003; Witzel, 2005) and one used a two-group comparison experimental design (Ives, 2007). See Appendix D for study design and number of participants. The number of participants included in the studies varied significantly. The lowest number of students with disabilities in a study was three (Strickland & Maccini, 2013) and the highest number of students with disabilities was 34 (Witzel et al., 2003). The studies were also conducted in different settings and students were taught by either the researcher or the general education mathematics teacher (see Table 5).

Table 5
Description of classroom setting and instructor

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Setting</th>
<th>Instructor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. (2007)</td>
<td>Special education only classroom setting</td>
<td>Researcher</td>
</tr>
<tr>
<td>Scheuermann et al. (2009)</td>
<td>Special education only classroom setting</td>
<td>Researcher</td>
</tr>
<tr>
<td>Strickland, T. and Maccini, P. (2013)</td>
<td>In a separate classroom setting</td>
<td>Researcher</td>
</tr>
<tr>
<td>Witzel et al. (2003)</td>
<td>Inclusive classroom setting</td>
<td>General education mathematics teacher</td>
</tr>
</tbody>
</table>
Two studies were conducted in special education only classroom settings (Ives, 2007; Scheuermann et al., 2009), two studies were conducted in an inclusive classroom setting (Witzel et al., 2003; Witzel, 2005) and one was conducted in a separate classroom setting (i.e., a separate room the instructor used within the school) (Strickland & Maccini, 2013). In three of the studies the researcher was the instructor (Ives, 2007; Scheuermann et al., 2009; Strickland & Maccini, 2013) and in two of the studies the students were taught by the general education mathematics teacher (Witzel et al., 2003; Witzel, 2005).

### 3.2 Description of MLD

In each of the five included articles the researcher used different criteria to determine the eligibility of participants based on their description of MLD (see Table 6).

Table 6

*Descriptions of the term MLD used as inclusion criteria*

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Description of MLD used as inclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. (2007)</td>
<td>Students had to be diagnosed with language-related disabilities (reading, writing and/or general language).</td>
</tr>
<tr>
<td>Scheuermann et al. (2009)</td>
<td>“Students had to be diagnosed with a learning disability according to state criteria, have a full-scale IQ standard score above 85, have a score below the 25th percentile on a standardized measure of mathematics achievement and demonstrate a deficit in the targeted skill (i.e., had to earn below 50% accuracy on a pretest measure for solving one-variable algebraic equations).” (p.106)</td>
</tr>
<tr>
<td>Strickland, T. and Maccini, P. (2013)</td>
<td>“Students had to (a) have a history of difficulties in the algebra domain of mathematics as evidenced by educational reports and teacher input; (b) be currently enrolled in Grade 8 or higher (when students typically participate in a formal Algebra I course in general education); (c) demonstrate a need for the intervention as evidenced by scoring below 60% on an investigator-developed measure; (d) be recommended by their mathematics teacher as being appropriate for this study; and (e) turn in a signed parent permission and student assent forms. All three participants were identified as having a learning disability and had mathematics goals on their Individualized Education Programs (IEPs).” (p.144)</td>
</tr>
<tr>
<td>Witzel et al. (2003)</td>
<td>“Students identified as having a learning disability were identified through school services as those who need additional support and who evidenced a 1.5 standard deviation discrepancy between ability and achievement. The students with learning disabilities who participated in the present study had mathematics goals listed in their individualized education plans.” (p. 123)</td>
</tr>
<tr>
<td>Witzel, B. (2005)</td>
<td>Students were diagnosed with a learning disability and had goals in mathematics.</td>
</tr>
</tbody>
</table>

Most authors (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel, Mercer, & Miller, 2003; Witzel, 2005) used the more general term learning disability instead of MLD. In addition to having an
identified learning disability, three authors (Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005) required that the participants had mathematics goals indicated on their Individual Education Programs (IEPs). Scheuermann et al. (2009) did not explicitly require mathematics goals, but did require that students had a diagnosed learning disability, score below the 25th percentile in mathematics on a standardized test and earned below 50% on a pretest measure before being included in the study. The description used by Ives (2007) was the most unique in that language-related disabilities (reading, writing and/or general language) were used as the descriptor; there was no direct mention of mathematics.

3.3 Interventions

After analyzing all of the included studies it was found that they all focused on the same algebra concept, solving equations. See Table 7 for an overview of the algebra content and interventions used. In the five included articles two interventions emerged: the concrete-representational-abstract (CRA) model and graphic organizers.

Table 7
Overview of Interventions

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Intervention</th>
<th>Algebra content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. (2007)</td>
<td>Graphic organizer</td>
<td>Systems of equations: Study 1 – two linear equations with two variables</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Study 2 – three linear equations with three variables</td>
</tr>
<tr>
<td>Scheuermann et al. (2009)</td>
<td>CRA model combined with EIR</td>
<td>One-variable equations</td>
</tr>
<tr>
<td>Strickland, T. and Maccini, P. (2013)</td>
<td>CRA-I model with the support of graphic organizers</td>
<td>Multiplication of linear expressions</td>
</tr>
<tr>
<td>Witzel et al. (2003)</td>
<td>CRA model</td>
<td>Transformation equations</td>
</tr>
<tr>
<td>Witzel, B. (2005)</td>
<td>CRA model</td>
<td>A series of algebra skills from simplifying two term expressions to solving linear equations with variables on both sides of the equal sign</td>
</tr>
</tbody>
</table>

3.3.1 CRA model

Different variations of the CRA model were used in four (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005) of the five included articles. The CRA model is used to help students make a connection between conceptual and procedural mathematics knowledge (Agrawal & Morin, 2016). It provides a framework for teachers that allows them to teach abstract concepts while concurrently providing concrete and visual representations (Agrawal & Morin, 2016; Steele & Steele, 2015).
Mathematical concepts are taught through three consecutive phases: first, the concrete phase; second, the representational phase and third, the abstract phase.

During the concrete phase of the CRA model students used physical objects to represent the terms of the equation and physically manipulated them to solve the equation (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005). Strickland and Maccini (2013) used algebra blocks and Scheuermann et al. (2009) used buttons and unifix cubes as the manipulative objects. In the studies by Witzel et al. (2003) and Witzel (2005) the representation of the variables was unique in that the coefficient and the variable were represented separately. Instead of using one colored block to represent $1x$ the same value was represented using one coefficient marker and one $x$ marker (Witzel et al., 2003; Witzel, 2005) (see Figure 1).

![Concrete representation of $-N + 10 = 3$](image)

To solve a concrete problem, students manipulate objects at each step towards the solution.

Figure 1. Concrete representation used in the studies by Witzel et al. (2003) and Witzel (2005).

In the representational phase, visual representations, in the form of drawings, other pictorial representations, graphic organizers or even virtual manipulatives, are used to help students move from the concrete use of manipulatives to more abstract thinking (Agrawal & Morin, 2016). In the studies by Witzel et al. (2003) and Witzel (2005) the pictorial representations closely resembled the manipulatives used during the concrete phase. Students drew the coefficient and the variable separately, and then drawings were made of how to correctly solve the equation. Students used drawings with tallies or dots, either alone or in combination with a graphic organizer, to represent the equations and the solution process (Scheuermann et al., 2009). Strickland and Maccini (2013) introduced the concrete and representational phases simultaneously and students drew the algebra blocks that were used during the concrete phase.

In the abstract phase, Arabic, or mathematical, symbols were used in all four of the studies (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005). Students wrote each step when solving the problem using only Arabic symbols (Witzel, 2005).
3.3.2 Graphic organizers

The fifth included article (Ives, 2007) used graphic organizers as an intervention when teaching solving systems of equations. Graphic organizers are visual representations, usually in the form of diagrams or charts, which show the relationships between ideas (Strickland & Maccini, 2010). Graphic organizers use symbols, or other visual representations, in place of language and can help to organize information or steps in multistep problems (Strickland & Maccini, 2010).

Ives (2007) presented two related studies involving the use of the same graphic organizer when solving systems of equations. In the first study, the graphic organizer was used to solve two linear equations with two variables, and in the second study, it was used to solve three linear equations with three variables. The graphic organizer consisted of three columns and two rows with Roman numeral column headings (see Figure 2).

<table>
<thead>
<tr>
<th>III</th>
<th>II</th>
<th>I</th>
</tr>
</thead>
</table>
| 2x + 4y + 2z = 16
-2x - 3y + z = -5
2x + 2y - 3z = -3 | y + 3z = 11
-y - 2z = -8 | z = 3 |
| 2x + 4(2) + 2(3) = 16
2x + 14 = 16
2x = 2
x = 1 | y + 3(3) = 11
y + 9 = 11
y = 2 | z = 3 |

Figure 2. Graphic organizer used in the study by Ives (2007).

Students were to begin in the upper left hand corner and work from cell to cell in a clockwise direction (Ives, 2007). The top row was used to combine equations until a one variable equation was produced and the bottom row was used to solve that one variable equation.

3.4 Implementation of interventions

The intervention duration in the four studies using the CRA model as the intervention varied from three lessons (Strickland & Maccini, 2013) to twenty-three lessons (Seuermann et al., 2009).

The CRA model was used without any modifications in the studies by Witzel et al. (2003) and Witzel (2005). Students were taught five concepts that became increasingly harder over 19 lessons. Both Witzel et al. (2003) and Witzel (2005) used algebra content that progressed from reducing simple two-statement expressions to solving more complex equations, including transforming equations with single variables. Each lesson in the 19-lesson sequence had the same four steps: introduce the lesson, model the new procedure, guide students through the procedure, and independent practice (Witzel et al., 2003; Witzel, 2005). The first lesson for each of the five concepts was taught concretely, the second lesson was taught representationally and the third and fourth lessons were taught abstractly (Witzel et al., 2003; Witzel, 2005).
Strickland and Maccini (2013) simultaneously introduced all three phases: concrete, representational and abstract, when teaching multiplication of linear expressions. They referred to this as the concrete-to-representational-to-abstract integration strategy (CRA-I). In addition, they used the support of graphic organizers in combination with the CRA model. The students were taught the concept of multiplication of linear expressions by embedding the expressions in area problems. This was taught over the course of three lessons. In the third lesson, the students moved from using the algebra blocks to a graphic organizer called the box method (Strickland & Maccini, 2013). Using the box method students were first to place the algebra blocks into the corresponding box on the graphic organizer, then they were to write the symbolic notation for each box and finally, they created their own box to multiply the linear expressions. This incorporated all three phases of the CRA model (concrete, representational and abstract) into one lesson.

The CRA model was combined with EIR in the study conducted by Scheuermann et al. (2009) to create an intervention strategy to help students solve one-variable equations. The EIR method used in this study consisted of explicit instruction, guided practice and the opportunity to explore a variety of algorithms (Scheuermann et al., 2009). “The EIR was comprised of three instructional components: explicit content sequencing, scaffolded inquiry, and systematic use of various modes of illustration” (Scheuermann et al., 2009, p. 106). In the first phase, the explicit content sequencing, students were explicitly taught one-variable equations in an order in which they became increasingly difficult. An example of the simplest was \( x + 3 = 10 \) and the most difficult was \( 3x + 2x - 4 = 51 \). This order was chosen specifically so that students would progress through the equations in a predefined manner and that they would be introduced to prerequisite skills and concepts before moving on to more difficult ones (Scheuermann et al., 2009). The scaffolded inquiry process was divided into three phases. During the first phase the teacher modeled the solution of equations by asking students how they would solve them and demonstrated their thinking. The teacher also pointed out “critical insights to the problem or questioned potential challenges the students could encounter” (Scheuermann et al., 2009, p. 107). The second phase of the scaffolded inquiry process was for students to use peer discussion to solve problems and discuss solution methods. Finally, in the third phase of the scaffolded inquiry process students were supposed to use a self-talk process, internal dialogue, to walk themselves through their thought process when solving equations (Scheuermann et al., 2005). During the final phase of this intervention, the various modes of illustration phase, the CRA model was used.

Graphic organizers were used to instruct students in solving systems of equations in the study by Ives (2007). Ives (2007) presented two related studies; both studies used the same graphic organizer. The first study involved two linear equations with two variables and the second study involved three linear equations with three variables. Although the content of the studies was different the execution was the same in both. Teachers used a combination of strategy and direction instruction approaches: they asked questions; provided feedback; administered probes; and included elaborate explanations, verbal modeling, and reminders (Ives, 2007). The first lesson was used to review prerequisite skills, the second presented
relatively simple systems of equations and the next two lessons introduced variations of systems of equations (Ives, 2007).

### 3.5 Outcomes of interventions

The outcome of the intervention in each of the included studies was evaluated using different measurement tools. However, all studies used some variation of pre-, post and follow-up, or maintenance, measurement (Ives, 2007; Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005), with the exception of the second study conducted by Ives (2007) where only pre- and post-tests were used (see Table 8). The outcomes in all five (Ives, 2007; Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005) articles were measured using either the number or the percentage of correct responses. Ives (2007), Scheuermann et al. (2009) and Strickland and Maccini (2013) also calculated the effect sizes of their interventions. The CRA model and the graphic organizer interventions both showed positive outcomes for students with MLD.

**Table 8**

*Test design and outcome measurements of included studies*

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Pretest</th>
<th>Posttest</th>
<th>Follow-up test</th>
<th>Outcome measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. (2007) – Study 1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Percentage correct of available points</td>
</tr>
<tr>
<td>Ives, B. (2007) – Study 2</td>
<td>X</td>
<td>X</td>
<td></td>
<td>Percentage correct of available points</td>
</tr>
<tr>
<td>Scheuermann et al. (2009)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Percentage of correct responses</td>
</tr>
<tr>
<td>Strickland, T. &amp; Maccini, P. (2013)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Percentage of correct responses</td>
</tr>
<tr>
<td>Witzel et al. (2003)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Number of correct responses</td>
</tr>
<tr>
<td>Witzel, B. (2005)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>Number of correct responses</td>
</tr>
</tbody>
</table>

The CRA intervention group and the comparison group, abstract only, were given a pretest, post-test and follow-up test that consisted of 27 items and was the same for all three-time points (see Table 9).
Table 9

Results From the Study by Witzel, Mercer and Miller (2003)

<table>
<thead>
<tr>
<th>Group</th>
<th>Maximum*</th>
<th>M</th>
<th>SD</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pretest CRA</td>
<td>2</td>
<td>0.12</td>
<td>0.41</td>
<td>7%</td>
</tr>
<tr>
<td>Pretest Abstract</td>
<td>2</td>
<td>0.06</td>
<td>0.34</td>
<td>7%</td>
</tr>
<tr>
<td>Posttest CRA</td>
<td>23</td>
<td>7.32</td>
<td>5.48</td>
<td>85%</td>
</tr>
<tr>
<td>Posttest Abstract</td>
<td>17</td>
<td>3.06</td>
<td>4.37</td>
<td>63%</td>
</tr>
<tr>
<td>Follow-up Test CRA</td>
<td>22</td>
<td>6.68</td>
<td>6.32</td>
<td>81%</td>
</tr>
<tr>
<td>Follow-up Test Abstract</td>
<td>21</td>
<td>3.71</td>
<td>5.21</td>
<td>78%</td>
</tr>
</tbody>
</table>

* Note: Total possible score is 27 for each measure

The CRA group outperformed the abstract only group on the posttest, having 23 and 17 correct responses respectively. Although, both groups maintained significant gains on the follow-up test, the gap between groups was smaller. The CRA group had 22 correct responses and the abstract only group had 21 correct responses (Witzel et al., 2003). Both groups showed significant improvement on the post and follow-up tests (Witzel et al., 2003). However, the CRA group outperformed the comparison group, abstract only, at a statistically significant level (Witzel et al., 2003).

The treatment group, the group using the CRA model intervention, and comparison group both showed improvement from the pretest to the posttest and on the follow-up test (Witzel, 2005). Students were assessed using a 27-item test with a medium difficulty level and were given the same test at all three measurement points. See Table 10 for an overview of all results.

Table 10

Results From the Study by Witzel (2005) p. 56

<table>
<thead>
<tr>
<th>Group</th>
<th>Pretest Mean, SD</th>
<th>Posttest Mean, SD</th>
<th>Follow-up Mean, SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment Group</td>
<td>0.18 (SD = 0.53)</td>
<td>8.26 (SD = 7.65)</td>
<td>7.96 (SD = 7.84)</td>
</tr>
<tr>
<td>Comparison Group</td>
<td>0.57 (SD = 1.12)</td>
<td>5.36 (SD = 5.75)</td>
<td>5.51 (SD = 5.97)</td>
</tr>
</tbody>
</table>

On the pretest the comparison group (0.57, SD = 1.12) outperformed the treatment group (0.18, SD = 0.53). However, on the posttest the treatment group (8.26, SD = 7.65) outperformed the comparison group (5.36, SD = 5.75). These gains remained on the follow-up test where the treatment group (7.96, SD = 7.84) continued to outperform the comparison group (5.51, SD = 5.97). Although, both groups showed improvement the treatment group outperformed the comparison group at a statistically significant level on both the posttest and follow-up test (Witzel, 2005).
All three participants, in the study by Strickland and Maccini (2013), showed substantial increases pre- to posttest, the pretest average scores ranged from 0-17% and the posttest average scores ranged from 78-93%. The students were tested using domain probes that were developed by the researcher and used as a pretest, posttest and maintenance test (Strickland & Maccini, 2013). All three were different, but covered the same algebra content at the same difficulty level. However, only two students maintained mastery, or a percentage of at least 80% correct, on the maintenance test that was given three to six weeks after the end of the intervention. One student was given the maintenance test three weeks after the intervention ended and scored 93%, one was given the maintenance test six weeks after and scored 98% and the third student was given the maintenance test four weeks after and scored 52%. The effect size for the intervention used by Strickland and Maccini (2013) was determined by the percentage of nonoverlapping data points and was calculated to be 100%, which represents a very effective intervention.

The outcomes for students with MLD, on two of the assessments used in the study by Scheuermann et al. (2009), showed improvement in the percentage of correct responses (see Table 11).

Table 11  
*Results From the Study by Scheuermann et al. (2009)*

<table>
<thead>
<tr>
<th>Statistics</th>
<th>Concrete Manipulation Test</th>
<th>Far-Generalization Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pretest</td>
<td>Posttest</td>
</tr>
<tr>
<td>Mean</td>
<td>38%</td>
<td>89%</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>0.22</td>
<td>0.12</td>
</tr>
</tbody>
</table>

The concrete manipulation test was designed to assess students while they concretely solved a one-variable equation embedded in a word problem (Scheuermann et al., 2009). On the concrete manipulation test, students showed an increase in the percentage of correct responses; going from 38% on the pretest to 89% on the posttest and 80% on the maintenance test. The far-generalization test was designed to assess students in solving one-variable word problems that were found in school textbooks. On the far-generalization test students also made gains; however, they were not as significant going from 21% on the pretest to 30% on the posttest. On both the concrete manipulation test and the far-generalization test students showed a statistically significant improvement in their scores (Scheuermann et al., 2009). Scheuermann et al. (2009), used Glass’s D to calculate effect sizes. Effect sizes were found between pretest and posttest means and pretest and maintenance means for three of the assessment measures used by the authors, the Concrete Manipulation Test, the Far-Generalization Test and KeyMath-Revised. All three showed moderate effect sizes (Scheuermann et al., 2009). According to the conclusions of the authors, the students in this study were able to solve a variety of one-variable equations and generalize the skills they learned to new problems of the same format and maintain these gains for up to 11 weeks. However, less
than 60% of the students showed significant gains so the increases in performance did not reach significant levels (Scheuermann et al., 2009).

The overall outcomes by Ives (2007) showed that all students, both the control group and the group using the graphic organizer, were able to make positive gains when solving systems of equations (see Table 12). Students were given a pretest, two posttests (one generated by the teacher and one generated by the researcher) and a maintenance test. The test was split into two sections the concept section and the system solving section, or problems section. The concept section was designed to measure whether students understood the concept behind the solution process (Ives, 2007). The system solving section was designed to evaluate whether or not students could correctly solve systems of equations. Ives (2007) presented two related studies involving the use of the same graphic organizer.

Table 12

Results From the Study by Ives (2007)

<table>
<thead>
<tr>
<th>Group</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage of available points</td>
<td>Percentage of available points</td>
</tr>
<tr>
<td>Control Group Concepts</td>
<td>62%</td>
<td>75%</td>
</tr>
<tr>
<td>Organizer Group Concepts</td>
<td>83%</td>
<td>87%</td>
</tr>
<tr>
<td>Control Group Problems</td>
<td>38%</td>
<td>26%</td>
</tr>
<tr>
<td>Organizer Group Problems</td>
<td>41%</td>
<td>62%</td>
</tr>
</tbody>
</table>

In the first study, it appears that the students who used the graphic organizers showed a higher conceptual understanding of solving systems of equations; they had a mean percentage of 83% correct responses whereas the control group had 62%. The concept section was compared across groups for the posttest and maintenance test and the group using the graphic organizers showed a statistically higher result ($F = 7.86, p = .009, \eta^2 = .219$) and the effect size, according to Cohen, was large (Ives, 2007). However, on the problem solving section both groups performed at a nearly equal level. The control group had 38% correct responses and the graphic organizer group had 41%. The effect size, according to Cohen, of the teacher-generated posttest was within the medium to large range ($F = 3.14, p = .087, \eta^2 = .101$). However, on the teacher-generated posttest the graphic organizer group showed a statistically significantly higher mean score (Ives, 2007).

In the second study, the group using the graphic organizer outperformed the control group at a statistically significant level on the problems portion of the test (Ives, 2007). The control group had a mean percentage of 26% correct responses and the graphic organizer group had 62% correct responses. The effect size, according to Cohen, on the system-solving section fell within the medium to large range. On
the concepts portion of the test the graphic organizer group outperformed the control group, but not at a statistically significant level (Ives, 2007). The control group had a correct response percentage of 75% and the graphic organizer group had 87% correct.
4 Discussion

The purpose of this systematic literature review was to identify, and critically analyze, existing interventions to assist students with MLD to solve equations in algebra. Five studies were identified, four focused on the CRA model and one focused on the exclusive use of graphic organizers as the modes of intervention. The results of the five studies will be discussed and used to answer the three research questions (1) What are the descriptions of MLD used in these studies? (2) What interventions have been studied for students with MLD in algebra? and (3) What were the outcomes on the algebraic learning of students with MLD?

4.1 Description of MLD used in these studies

There are a variety of terms that can be used to describe MLD. In each of the five articles reviewed the researchers used different criteria to determine the eligibility of participants based on their description of MLD. No two authors used the exact same inclusion criteria. This can make it difficult to generalize findings from the studies. For instance, in the study by Ives (2007), the students included as participants had to have a diagnosed language-related disability. Ives (2007) used a description of dyscalculia defined by Geary (2004) that attributes student’s mathematics difficulties to deficits in semantic memory. Research has demonstrated a high comorbidity between this type of dyscalculia and language-related disabilities (Agrawal & Morin, 2016; Geary, 2004; Ives, 2007; Shin & Bryant, 2015). Due to this link between mathematics and language-related disabilities Ives (2007) chose to limit the inclusion criteria for his studies to students that had a diagnosed language-related disability.

However, some students included in the studies did have MLD they were not the main focus (Ives, 2007). This is obvious when looking at the percentages of students with MLD in each of the studies. In the graphic organizer group of the first study 21% had MLD and in the control group 13%, had MLD. In the graphic organizer group of the second study 20% had MLD and in the control group 40% had MLD. There was some comorbidity among learning disabilities, but the author did not distinguish how many students had overlapping diagnoses and what they were. Ives (2007) hypothesized, that the use of graphic organizers would lower the amount of verbal elements used when teaching mathematics. Therefore, students with language-related disorders, and students with MLD, would benefit. The results suggested that the students who used the graphic organizers showed a higher conceptual understanding, but hence, it is difficult to generalize those findings to students with only MLD (Ives, 2007). Even though there were limitations, the outcomes of the intervention seem promising when teaching students with MLD.

Different inclusion criteria were also used in the four CRA model intervention studies. Although, the descriptions were more similar in that they all included mathematics (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005). Strickland and Maccini (2013), Witzel et al. (2003) and Witzel (2005) required that students had a diagnosed learning disability and had goals in mathematics on their individualized education programs (IEPs). Research supports the criteria they used in that many stu-
dents with MLD show difficulties in mathematics, which would be evidenced by the mathematics goals on their IEPs (Shalev et al., 2007; von Aster & Shalev, 2007). In the study by Scheuermann et al. (2009) Geary’s (2004) criteria for diagnosing MLD was used; the students included as participants had to score below the 25th percentile on a standardized test and have an IQ in the normal range. Even though the authors used different criteria to describe MLD, all of the studies showed favourable outcomes.

4.2 Vygotsky’s theory of cognitive development

The results from all five studies are supported by Vygotsky’s theory of cognitive development. The CRA model and graphic organizers are both based on the principles of the zone of proximal development and scaffolding (Kozulin, 2003; Olson & Pratt, 2000). When using the CRA model students are given scaffolds, in the form of concrete manipulatives and pictorial representations, to help them reach beyond the thinking that they could do on their own (Gredler, 2012). Those scaffolds are gradually taken away and replaced with Arabic, or mathematical, symbols. The CRA model should help students’ advance in their thinking and understanding of abstract mathematical concepts and by the final phase they should progress to the use of mathematical symbols (Agrawal & Morin, 2016). The goal of the CRA model is to help students understand abstract concepts that would be beyond their reach without the help of the concrete manipulatives and pictorial representations. Graphic organizers also use elements of Vygotsky’s theory of cognitive development. The graphic organizer is the scaffold that is used to structure student thinking and support student learning. In the study by Ives (2007) students were guided through the steps of finding the solution to the systems of linear equations. In all studies, students were able to demonstrate cognitive development, through the increases in their performance, while being supported with scaffolds within their zone of proximal development.

Agrawal and Morin (2016) discuss how research has recently shown that students should master each phase in the CRA model before moving onto the next phase. In three (Scheuermann et al., 2009; Witzel et al., 2003; Witzel, 2005) of the four studies where students were taught using the CRA model they were required to master one sequence before moving onto the next. The students had to show that, on their own, without help, they were able to concretely represent abstract concepts such as one-variable equations, and solve them. Only then, were they able to move on to the representational sequence in the CRA model. Then the concrete manipulatives scaffold was removed and students were to advance their thinking and could no longer rely on the use of manipulatives. Once the representational phase was mastered then that scaffold was removed and students were meant to replace the drawings with Arabic symbols. The students made gains and showed positive outcomes in all three of those studies (Scheuermann et al., 2009; Witzel et al., 2003; Witzel, 2005). However, in the study by Scheuermann et al. (2009) the CRA group did not outperform the comparison group at significant level.

All three phases of the CRA model: concrete, representational and abstract were introduced simultaneously in the study by Strickland and Maccini (2013). Agrawal and Morin (2016) discussed that generaliz-
ing the conceptual understandings from the concrete and representational phases and applying them to the abstract phase is a difficult task for students with MLD. However, Strickland and Maccini (2013) hypothesized that by integrating and connecting the concrete, representational and abstract sequences during instruction, and through supporting students during this process, students with MLD would achieve a better understanding of the concept being taught and would be more likely to generalize their learning. In their study, all three students showed significant gains in pre- to posttest scores (Strickland & Maccini, 2013). However, only two students maintained mastery on the follow-up test given three to six weeks after the end of the intervention. The results suggest incorporating all three phases and introducing them at the same time may help students explicitly make the connections between the concrete and abstract phases of the model. Although, it is difficult to generalize their findings as the study only included three students and all lessons were taught in a separate setting by the researcher. Therefore, it is unclear how this instruction method would work in an inclusive classroom setting where a general education mathematics teacher taught all students. However, the results are promising and it may be beneficial for students with MLD to see the explicit connections among all three phases of the CRA model.

4.3 Explicit inquiry routine

The CRA model relies on components of the EIR, namely that teachers use modeling, guided practice and independent practice when teaching abstract concepts. Students are explicitly instructed in how to represent the concept using concrete manipulatives. They are also guided through the use of pictorial representations to represent the abstract concept being taught. Gersten et al. (2009) noted that the EIR is often used in conjunction with other instructional methods. Although, only one study (Scheuermann et al., 2009), directly mentioned the incorporation of the EIR with the CRA model all of the studies used some component of EIR. In the study by Witzel et al. (2003) the modeling, guided practice and independent practice components of the EIR were used. Witzel (2005) incorporated components of EIR in each lesson taught; students were given an advanced organizer, description of the activity, modeled the steps, guided practice through the steps and independent practice. In the study by Strickland and Maccini (2013) students were taught through explicit instruction and during the lessons the researcher used modeling, guided practice and independent practice. Ives (2007) used the fewest components of the EIR model, but still incorporated verbal modeling and providing feedback into lessons. Agrawal and Morin (2016) discussed that in order to be able to effectively teach the CRA model components of explicit instruction must be used. This may explain why the studies that used the CRA model as an intervention used more components of EIR than the study that used graphic organizers.

Overall, both interventions, the CRA model and graphic organizers, appear to positively affect the learning outcomes of students with MLD when solving equations. However, it is difficult to identify what exactly caused the change in outcomes because all interventions used a combination of strategies. The CRA model requires components of EIR during instruction. Therefore, it is difficult to separate if the
CRA model or the EIR caused the gains in student learning. In the same way, the graphic organizer intervention was combined with components of direct instruction and EIR. That also makes it difficult to determine if the positive outcomes achieved were because of the intervention or the instructional strategy. However, most mathematics teachers tend to use components of EIR in their regular instruction. So, the use of EIR may be consistent between intervention and control groups. In which case, the intervention would be responsible for the positive outcomes seen in the included studies. In addition, since both types of interventions showed improvements for all students using the EIR method it may be valuable in inclusive classroom settings.

4.4 Factors that may influence the outcomes of the interventions

Through the analysis process three factors that could have influenced the outcomes of the interventions were noticed. They are: the setting and the instructor during the intervention, and the duration of the intervention.

Two of the studies (Witzel et al., 2003; Witzel, 2005) were conducted in inclusive classroom settings and students were instructed by their general education mathematics teacher. These were the only studies that reflected the reality of inclusive classroom settings. In the other three studies (Ives, 2007; Scheuermann et al., 2009; Strickland & Maccini, 2013) students were taught by the researcher. The schools chosen for the studies by Ives (2007) and Scheuermann et al. (2009) were special in that every student attending the school had a diagnosed learning disability or behaviour disorder. This is not representative of reality in that most students attend schools where there is a mix of students with special educational needs and typically developing students. Strickland and Maccini (2013) only instructed three students and they were taught outside of the regular education classroom setting. Again, this is not realistic in that students with MLD are now being educated within the inclusive classroom setting. Therefore, it is difficult to know if the results achieved in the three studies by Ives (2007), Scheuermann et al. (2009) and Strickland and Maccini (2013) can be implemented in inclusive classroom settings, by general education mathematics teachers, and maintain the same outcomes. In addition, the studies conducted by Scheuermann et al. (2009) and Strickland and Maccini (2013) did not include any typically developing students. So, it is unknown how their learning will be impacted. However, the two studies by Witzel et al. (2003) and Witzel (2005) showed that all students taught using the CRA model, both students with learning disabilities and students without learning disabilities, improved their performance at a statistically significant level. This appears to support the findings of Scheuermann et al. (2009) and Strickland and Maccini (2013), and may allow their findings to be generalized to inclusive classroom settings. Neither the setting nor the instructor appears to have negatively influenced the outcomes of the interventions.

The durations of the CRA model interventions varied from three lessons (Strickland & Maccini, 2013) to 23 lessons (Scheuermann et al., 2009). The two studies by Witzel et al. (2003) and Witzel (2005) both included a 19-lesson sequence. However, the duration of the interventions does not appear to impact
the outcomes achieved, as all four studies showed substantial positive gains in student achievement. Three studies (Scheuermann et al., 2009; Witzel et al., 2003; Witzel, 2005) included statistically significant improvements in student outcomes. This has important implications for teachers. Namely, that the intervention does not require a large time commitment and could even be implemented a few lessons before an assessment. The graphic organizer intervention conducted by Ives (2007) consisted of four lessons, but since it was the only included study with that intervention there is nothing to compare the outcomes to. Therefore, it is unknown how the duration of the intervention influences the outcomes.

4.5 Discussion of interventions

The CRA model has mostly been researched in the elementary education setting on concepts that lend themselves to easy concrete representations; like addition, subtraction, place value and fractions (Agrawal & Morin, 2016; Witzel et al., 2003). Witzel et al. (2003) criticized the way that the CRA model had been used in other algebra studies. They suggested that the concrete materials used in other studies were not effectively teaching the algebra concepts and would not allow students to generalize later to more difficult concepts (Witzel et al., 2003). This is why Witzel et al. (2003) and Witzel (2005) adapted the concrete and representational phases to have students represent the coefficient and variable separately. The studies by Scheuermann et al. (2009) and Strickland and Maccini (2013) represented the coefficient and variable together and used lower-level algebra concepts compared to the studies by Witzel et al. (2003) and Witzel (2005). Therefore, it cannot be determined if the criticism by Witzel et al. (2003) is correct based on the analyses of the studies reviewed.

Ives (2007) also critiqued the CRA model and suggested that it does not lend itself to more abstract, higher-level mathematics concepts that cannot be demonstrated concretely. None of the reviewed CRA model studies included algebra content at the same level as Ives (2007). They all assessed lower-level algebra concepts. Therefore, it is unknown, from the analyses of these studies, if Ives (2007) is correct in his criticisms. Even though the CRA model used in the four studies that were reviewed (Scheuermann et al., 2009; Strickland & Maccini, 2013; Witzel et al., 2003; Witzel, 2005) showed promising results there is not a consensus on how effective it is and this calls for further research before any conclusions can be drawn.

Due to these criticisms of the CRA model, Ives (2007) discussed that graphic organizers tend to be more easily applied to higher-level algebra concepts, such as systems of equations. Additionally, Ives (2007) pointed out the comorbidity between language-related disorders and MLD, and hypothesized that the use of graphic organizers would limit the amount of verbal elements and reading and instead replace those elements with mathematical symbols and equations. Therefore, the graphic organizer would provide support to students with language-related learning disabilities, as well as students with MLD, when solving systems of equations. The results of the study are encouraging and students using the graphic organizer outperformed the control group. Although, the results were not consistent across the two studies and both studies had a small sample size. Also, some students in each study had only MLD without a lan-
guage-related disorder and their results were not presented separately. Therefore, it is difficult to determine if the use of the graphic organizer would support students with only MLD. However, it appears that the limited language and the added structure of graphic organizers may benefit students with MLD and students with language-related disorders.

4.6 Practical implications

This review aimed to identify effective interventions for teaching algebra to students with MLD in an effort to improve student achievement. Through the analysis of the included studies five main practical implications for teachers emerged.

First, both the CRA and graphic organizer interventions provide concrete methods for improving student achievement. Both are based on an established theory of children’s cognitive development, Vygotsky’s theory. Both of these intervention strategies are easily implemented in inclusive classroom settings. Aside from the need for manipulative materials when using the CRA model, neither requires other additional materials nor extra planning time to implement.

Second, the duration of the CRA intervention did not impact learning outcomes. Even interventions that took place over very few lessons showed statistically significant improvement in student outcomes. Therefore, the CRA model could be effective in increasing student achievement over small time periods (e.g., before an assessment).

Third, the outcomes were not influenced by who instructed the intervention. The students instructed by the general education mathematics teacher showed an improvement, as did the students instructed by the researcher. Therefore, it appears that the CRA model could be an effective intervention in an inclusive classroom setting.

Fourth, similarly, the intervention setting did not impact the outcomes achieved by the students. The students taught in an inclusive classroom setting showed gains the same as those taught either in a special education only classroom or a separate setting. Therefore, these interventions appear to be effective even in a realistic, inclusive classroom setting.

Fifth, in the studies where intervention groups included both students with and without learning disabilities all students showed an increase in learning outcomes. Therefore, it appears that these interventions, the CRA model and graphic organizers, are helpful in increasing student achievement for all students in an inclusive classroom setting.

4.7 Discussion of quality assessment

The overall quality of the included articles was either medium or high. The most common reason for medium quality is that the study had a low sample size when compared to studies of a similar nature.
This is common for intervention studies, but still might make it difficult to generalize the findings. However, it was not enough of a limitation to dismiss the findings or exclude the studies for this systematic literature review. Since all of the articles showed either medium or high quality in the analysis methods of their study, no emphasis was placed on any particular study when completing the data analysis for this review.

4.8 Methodological issues

The systematic review process used for this critical literature review had advantages and disadvantages. One advantage is that the detailed description of the process makes it possible for another researcher to replicate the search. As was evidenced during the peer-review process. A disadvantage is that not every database associated with education was searched, so some articles may have been missed. For example, due to the complex indexing system used in Sage journals, this database was not searched. However, some articles published in Sage were found in the ERIC database. Although, it is not known if all articles published in Sage are included in ERIC. Yet, the systematic review process used was exhaustive enough and appropriate for this type of systematic literature review.

Only the author completed the abstract and full-text screening. This could have resulted in some articles being excluded that may have actually met the inclusion criteria. The use of a peer-review process was meant to help lower that risk, but a second reviewer did not look at all abstracts or articles found during this process. However, the one article that was found and included during the peer-review process was eventually excluded during the full-text screening because it did not actually meet the inclusion criteria for the study. Additionally, the author designed the protocol used for the screening and data extraction process. The peer-review process was also structured to help validate the protocol, but because it was reviewed for two included and two excluded articles it was not fully validated. However, all data that was used in the results section could be located in the protocol so it appears that it was effective in its design. The protocol was also adapted specifically to this study and the results found in the included articles, which increases its reliability for this study. A limited definition of algebra was used because it was preferential for making comparisons among articles. Although, if the definition had been broader it may have resulted in more articles being included. Also, including the word equation in the search terms may have found articles relevant to this study. Since some titles or abstracts may have used the term equation instead of algebra.

4.9 Limitations

There are five main limitations to the conclusions of this review. First, despite having a well-conducted search, there may have been some limitations during the search process. The search terms were not adapted to each database and that could have affected the results. Although, the search terms used were well structured and relevant for the scope of this systematic literature review. Second, the author was the only reviewer. There was a peer-review process to help ensure no articles were missed and to help val-
idate the protocol. High agreement rates were achieved during the process, which makes it likely that the review process was thoroughly executed. Third, the author designed the protocol and quality assessment tool. Although, the protocol was well designed and adapted to this specific review and the quality assessment was based on a researched method. Fourth, not all education databases were searched. However, the search was exhaustive enough and within the scope of this review. Fifth, the definition of algebra used for this review was very strict. The definition of algebra used was based on research and allowed for studies to be easily compared.

4.10 Future research

There are several implications for future research based on the findings in this review. As more and more students with MLD are being educated in inclusive classroom settings there also needs to be more research conducted in inclusive classroom settings. Along those same lines, more research needs to be conducted where the general education mathematics teacher is the instructor during the intervention. This would better represent the reality for a majority of teachers and students with MLD, and also make it easier for teachers to be able to predict the effectiveness of interventions used in their classrooms. The only studies found within the area of algebra were focused on solving equations. This implies more research should be done in other areas of algebra. In addition, more intervention studies could be done in other higher-level, algebra concepts. This would help to ensure students with MLD were able to succeed in all areas of algebra beyond just solving equations.
5 Conclusion

With the new high school graduation demands teachers need to be prepared to help all students succeed. Especially, students with MLD, who have been shown to achieve at a lower rate than students without learning disabilities and who may need interventions to be able to succeed in algebra. The CRA model seems to demonstrate it can be used successfully in a variety of scenarios involving solving equations. The use of graphic organizers also appears to be helpful when teaching higher-level algebra content that may be difficult to represent concretely.

This review discovered several practical implications for teachers. Namely, that the CRA model of intervention is easy to implement, effective over short periods of time and appears to positively influence the achievement of all students in an inclusive classroom setting. The graphic organizer showed similar results in that it is easy to implement and appears to improve all students learning in an inclusive classroom setting. This review provided a good starting point for teachers to identify interventions that could be useful in algebra; however, more research still needs to be done.
References

* References marked with an * indicate studies included in the systematic literature review


Appendix A

Search results flowchart

ERIC – 21 results
Web of Science – 9 results
JSTOR – 122 results
Science Direct – 108 results
SCOPUS – 11 results
Academic Search Elite – 14 results

285 articles

34 duplicates

251 articles used for abstract review

1 article found during peer-review

239 articles excluded*
- 129 did not mention MLD
- 10 did not involve school-aged children
- 4 did not involve the classroom setting
- 31 did not include classroom-based interventions
- 51 did not include algebra

13 articles used for full-text review

4 articles found during hand search of references, reviewed at full-text

10 articles excluded
- 2 did not include classroom-based interventions
- 5 did not include algebra
- 3 were reviews

3 articles included

2 articles included

5 articles included

2 articles excluded
- 1 did not include algebra
- 1 was a review

*more than one reason for exclusion is possible, but the majority of the excluded articles did not have a specific focus on math learning disabilities
Appendix B

Thesis protocol

<table>
<thead>
<tr>
<th>Thesis Protocol – Abstract Level (also used at the Full-Text level)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Authors:</strong></td>
</tr>
<tr>
<td>Definition</td>
</tr>
<tr>
<td>Setting</td>
</tr>
<tr>
<td>Age</td>
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<tr>
<td>Intervention type</td>
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<tr>
<td>Math</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Thesis Protocol – Full-text Level</th>
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</thead>
<tbody>
<tr>
<td><strong>Quality Assessment</strong></td>
</tr>
<tr>
<td>Was the research conducted an empirical study?</td>
</tr>
<tr>
<td>Sample size:</td>
</tr>
<tr>
<td>Informed consent:</td>
</tr>
<tr>
<td>Disability:</td>
</tr>
<tr>
<td>Analysis method:</td>
</tr>
<tr>
<td>Effect sizes:</td>
</tr>
</tbody>
</table>
| **Purpose** | Outline the purpose of the study.  
Were the purpose (aim) and/or research questions stated clearly?  
What were the research questions? |
|---|---|
| **Theory** | Describe the theoretical or philosophical perspective of this study.  
Was the theoretical perspective identified? |
| **Problems** | What were the specific content problems students with math learning disabilities were struggling with?  
Did the article address what content the students were experiencing difficulty with in algebra? |
| **Interventions** | What interventions were suggested?  
How was the intervention implemented?  
For how long?  
Describe the scientific basis for the interventions used.  
Who was the instructor during the intervention?  
Were the interventions clearly identified? |
| **Measurement tools** | What assessments were given?  
How were the outcomes measured? |
| **Results** | What were the results of the intervention? Were any statistically significant outcomes seen? |
| **Outcomes** | What were the outcomes of the intervention?  
Were the outcomes of the intervention clearly described? |
| **Conclusions and Implications** | What did the study conclude? What are the implications of these results for your professional field?  
Were the conclusions clearly stated? |
<table>
<thead>
<tr>
<th>Author, Year and Title</th>
<th>Purpose</th>
<th>Description of Learning Disability</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ives, B. (2007). Graphic Organizers Applied to Secondary Algebra Instruction for Students with Learning Disorders.</td>
<td>“The purpose of this investigation was to address the following three research questions: 1) Will secondary students with learning disabilities or attention disorders who have been taught to solve systems of two linear equations in two variables with graphic organizers perform better on related skill and concept measures than students instructed on the same material without graphic organizers? 2) Will the difference in performance cited in the first research question be maintained for 2–3 weeks after instruction and immediate posttesting are completed? 3) Will the findings of the first question be replicated when graphic organizers are used to teach secondary students with learning disabilities or attention disorders to solve systems of three linear equations in three variables? ” (p. 111)</td>
<td>Students had to be diagnosed with language-related disabilities (reading, writing and/or general language).</td>
<td>“The results of these two studies consistently showed that students who worked with the graphic organizers had a stronger grasp of the conceptual foundations for solving systems of linear equations than did the students who did not work with the graphic organizers based on their performance on the conceptual sections of the investigator-generated tests. This advantage in conceptual understanding was maintained over a few weeks in Study 1.” (p. 117)</td>
</tr>
<tr>
<td>Scheuermann, A., Deshler, D. and Schumaker, J. (2009). The Effects of the Explicit Inquiry Routine on the Performance of Students with Learning Disabilities on One-Variable Equations.</td>
<td>“Specifically, the study was designed to examine the effects of the instruction on one-variable equations embedded in word problems by assessing students’ ability to (a) representationally and abstractly illustrate and solve problems over time, (b) concretely illustrate and solve problems over time, (c) transfer skills learned with simple equations to more complex equations, and (d) transfer skills learned to word problems found in typical algebra textbooks.” (p. 106)</td>
<td>“Students had to be diagnosed with a learning disability according to state criteria, have a full-scale IQ standard score above 85, have a score below the 25th percentile on a standardized measure of math achievement and demonstrate a deficit in the targeted skill (i.e., had to earn below 50% accuracy on a pretest measure for solving one-variable algebraic equations).” (p. 106)</td>
<td>“The results of this study show that students with MLD can learn to solve a variety of one-variable equation word problems using multiple modes of illustration (i.e., C-R-A). Further, the study shows that students with MLD can generalize the skills they have learned to novel problems written in the same format as the instructed problems and to more complex problems than the instructed problems and maintain these increases for up to 11 weeks. More important, students transferred their newly learned skills to a variety of situations. The findings of the present study support the use of explicit instruction (i.e., clear, detailed and sequential instruction) to improve student mathematical performance. “ (p. 118)</td>
</tr>
</tbody>
</table>

“The overall purpose of this study was to determine the effectiveness of the CRA-I strategy with the support of a graphic organizer to teach the skills and concepts associated with multiplying linear expressions embedded in area word problems. In addition, the NCTM process standards were embedded throughout the intervention.” (p. 144)

Students had to “(a) have a history of difficulties in the algebra domain of mathematics as evidenced by educational reports and teacher input; (b) be currently enrolled in Grade 8 or higher (when students typically participate in a formal Algebra I course in general education); (c) demonstrate a need for the intervention as evidenced by scoring below 60% on an investigator-developed measure; (d) be recommended by their mathematics teacher as being appropriate for this study; and (e) turn in a signed parent permission and student assent forms.” (p. 144)

“On the posttest and follow-up exams, the students who participated in CRA instruction outperformed the students who participated in traditional abstract instruction.” (p. 128)

- “The results from this study indicate that the CRA-I strategy offers promise as an intervention for assisting secondary students with LD to develop procedural fluency when multiplying two linear expressions to form a quadratic expression and to develop the conceptual understanding of the linear and quadratic expressions as generalizing statements relating to an area problem.

- This strategy may be effective within an inclusive middle or high school algebra classroom as a method of differentiated instruction and as a Tier 2 or Tier 3 intervention.” (p. 152)


“The purpose of this research was to test the effectiveness of a new explicit CRA algebra model that was designed to represent more complex equations. Although other programs were effective as short-term interventions, this model provides representational processes and procedures that are appropriate for both beginning and advanced algebra topics by allowing students to work with every algebra component within an equation.” (p. 122)

“Students identified as having a learning disability were identified through school services as those who need additional support and who evidenced a 1.5 standard deviation discrepancy between ability and achievement. The students with learning disabilities who participated in the present study had math goals listed in their individualized education plans.” (p. 123)

“Prior to the present research study, there has not been a published examination of a manipulative and pictorial method that translates into more complex equations beyond simply solving for single inverse operations. Not only was the present CRA sequence of instruction model applicable to equations with coefficients other than one, but also the students were able to make significant gains from pretest to posttest in solving algebraic transformations.” (p. 129)
“Since this CRA model was taught to diverse learners in mainstream classrooms, the CRA sequence appears to be effective within whole-class settings characteristic of inclusion models.” (p. 129)

- “The purpose of this study was to compare the benefits of this multisensory CRA algebra model to those of traditional abstract instruction with middle school students in inclusion settings.” (p. 51)

- “The results favoured the treatment group who learned through multisensory algebra over the comparison group who learned through traditional abstract explicit instruction. Both the treatment and the comparison group showed improvement from the pretest to posttest and follow-up tests.” (p. 55)

- “The results support CRA instruction for middle-school students who need remediation in math; they also support the use of CRA techniques for students with a history of high math achievement.” (p. 58)

- “The apparent success of the CRA model shows promise for inclusive settings where students are highly varied in their math abilities. The varied success across students illustrates how the model may benefit not only students who are struggling in math but also those who have a successful history in math.” (p. 58)
### Appendix D

**Study design and number of participants**

<table>
<thead>
<tr>
<th>Author and year</th>
<th>Study design</th>
<th>Number of participants</th>
</tr>
</thead>
</table>
| Ives, B. (2007) – study 1 | Two-group comparison experimental | Graphic organizer group: 10 students with language-related disabilities, 4 students without disabilities  
Control group: 11 students with language-related disabilities, 5 students without disabilities |
| Ives, B. (2007) – study 2 | Two-group comparison experimental | Graphic organizer group: 8 students with language-related disabilities, 2 students without disabilities  
Control group: 8 students with language-related disabilities, 2 students without disabilities |
Comparison group: 34 students with disabilities, 154 students without disabilities |
| Witzel, B. (2005) | Random assignment of clusters | Treatment group: 26 students with disabilities, 82 students without disabilities  
Comparison group: 23 students with disabilities, 100 students without disabilities |