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Algebra Instruction for Secondary Students With Learning Disabilities: A Review

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The purpose of this article was to evaluate the quality of research studies and the evidence base for algebra instruction for secondary students with learning disabilities (LD) from 2000 to 2020. We evaluated the quality of methodological rigor of a total of eight single subject and three group design research studies using the 2014 Council for Exceptional Children (CEC) quality indicators for evidence-based practices for special education. Results indicated that two studies met the criteria for high-quality or acceptable research based on absolute coding, whereas nine studies met the standards for an evidence-based practice based on weighted coding. Implications for future research and practice are discussed.

Keywords: **Algebra Instruction, Secondary Students, Learning Disabilities, Evidence-Based Strategies, Math Instruction**

Introduction

Algebra is critically important as it "is a gatekeeper course because it is a prerequisite for the high school mathematics and science courses considered essential, if not required, for getting into college" (Heppen et al., 2011, p. 3). Algebra also serves as a foundational skill for many careers including several STEM fields. Math requirements may be an obstacle for many students on their path to postsecondary education (Postelnicu, 2011). Rickles et al. (2017) found that less than half of ninth-grade students enrolled in Chicago Public Schools in 2010 or 2011 who failed Algebra 1 were able to recover the course credit by the end of high school, equating to 10% of the overall student population. Currently, 20 states and the District of Columbia require students to take Algebra II in order to graduate from high school. However, one study concluded that the Algebra II completion rate remained steady at about 10 percentage points lower for Black students compared to White students from 2007 to 2015 in Texas (Stoker et al., 2018). The same study found that Algebra II completion rates were significantly lower for economically disadvantaged students over the same time period. Hacker (2012) maintains that the biggest impediment to graduation from college remains mastery of freshman-level mathematics courses. Algebra performance is the leading predictor of college and work success (Achieve, 2013).

Students with learning disabilities (LD) would be considered part of the high-risk group for not completing algebra. Students with LD have average or above average intelligence but they have deficits in language, attention, memory, visual-processing, and other cognitive areas which may impact their math performance. Students with LD often struggle in understanding, conceptualizing, and applying

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higher-level algebra skills (Marita & Hord, 2016). Since algebra is the foundation for higher level math courses, it is crucial to identify evidence-based strategies (EBPs) to improve algebra achievement of secondary students with LD.

The expectations for math instruction as recommended by the National Council of Teachers of Mathematics (NCTM, 2019) include understanding patterns, relations, and functions; representing and analyzing mathematical situations and structures using algebraic symbols; using mathematical models to represent and understand quantitative relationships; and analyzing change in various content. All of these recommendations apply to students learning algebra, and expectations of the mastery of these recommendations are much higher for grades 9 through 12.

Previous Algebra Reviews

Several reviews have been conducted to study the impact of interventions to improve algebraic performance of students with LD. Maccini and colleagues (1999) reviewed six algebra studies for secondary students and concluded that algebra achievement of students with LD improves with instruction on domain-specific knowledge, problem-solving, and self-regulation strategies. Successful interventions included instruction of word problems systematically using concrete, representational and abstract sequence of instruction.

A review of algebra instruction for elementary and secondary students with LD and at-risk for LD conducted by Hughes et al. (2014) included eight experimental studies. Cognitive/model-based interventions which included systematic and explicit instruction as a feature were found to be most effective followed by concrete-representational and abstract sequence of instruction and technology-based interventions.

Watt and colleagues (2016) conducted a review of algebra interventions for students with LD across 3rd to 12th grades. They addressed the alignment of algebra skills with Common Core State Standards (CCSS). Based on the analysis of 15 studies, five interventions for algebra emerged as being most effective. These included: (1) Concrete-representational-abstract sequence of instruction, (2) cognitive strategy instruction (CSI), (3) enhanced anchored instruction (EAI), (4) tutoring, and (5) graphic organizers.

Previous studies did not include quality indicators to evaluate the individual studies included in the reviews. Quality indicators can be used to determine whether a research study is methodologically sound. This is one required factor in determining if a strategy is evidence-based. This review will apply quality indicators to gauge the body of evidence supporting algebra strategies. Although algebra is taught at the elementary level, we chose to evaluate the studies on the secondary level. Prior to the secondary level, algebra is embedded in other math content, but at the secondary level algebra is presented as one of the required courses for high school graduation.

The need for supporting students' learning through the use of evidence-based practices is widely acknowledged and is even mandated by the Every Student Succeeds Act and Individuals with Disabilities Education Act (West, 2016). Nowhere is there more of a need for EBPs than in the field of special education. In the past, questionable practices have been used to support students with disabilities, such as modality instruction (Burns & Ysseldyke, 2009) and covered overlays to mitigate visual stress for students with dyslexia (Uccula et al., 2014). By definition, students eligible to receive special education services are struggling academically; they can ill afford time and effort spent on ineffective practices that do not actually support their learning.

History of QIs

To that end, in 2005 Gersten and colleagues and Horner and colleagues developed quality indicators (QIs) that could be applied to experimental and single subject research in order to determine and establish evidence-based strategies in the special education field. The development of these QIs was described as "pioneering work" (Cook et al., 2015, p. 220). However, some of these earliest QIs are difficult to operationally define and require that experimental and single subject research be considered separately rather than collectively. What Works Clearinghouse has also developed QIs for research that require separate consideration for group design and single subject research (Kratochwill et al., 2013; What Works Clearinghouse, 2017). In 2014, the Council for Exceptional Children (CEC) established an integrated set of QIs that could be applied to a body of qualitative research to determine whether or not a strategy was research-based (although some of the indicators apply only to one design or the other). Unlike the QIs established by Gersten et al. (2005) and Horner et al. (2005), the authors of the CEC standards specify that all QIs must be met for each study, arguing that all QIs are "essential" (Cook et al., 2015, p. 221). However, Royer and colleagues (2017) have since recommended the use of a weighted system rather than an absolute system in order to include valuable research that contributes to the evidence base.

The purpose of our review was to evaluate the quality of research and evidence base for algebra instruction for secondary students with LD. Quality indicators were not used in any of the previously discussed reviews. This review specifically addressed the question: How well do studies that examine algebra instruction at the secondary level meet the QI guidelines in order to be deemed methodologically sound?

Method

The researchers conducted a search of peer-reviewed research articles focusing on algebra instruction for secondary students with LD from January 2000 through December 2020 to replicate and extend the review of literature done by Watt and colleagues (2016). First, they searched the electronic databases of ERIC, PsycINFO, and Education Research Complete using key terms such as *algebra, algebraic expressions, and equations.* Each keyword was combined with the search terms describing the population *(i.e., learning disabilities, learning problems, mathematical disabilities, math learning disabilities*). Second, we searched the reference lists of relevant review articles (Gagnon & Maccini, 2001; Hughes et al., 2014; Watt et al., 2016; Witzel et al., 2001) and conducted an ancestral search of reference lists of identified studies. In this process, we identified research (i.e., Scheuermann et al., 2009) whose work did not show up in the initial databases search using key terms. We also hand searched the following journals: *Exceptional Children, Journal of Learning Disabilities, The Journal of Special Education, Learning Disabilities Research & Practice, and Learning Disabilities Quarterly*. One additional article was identified during the hand search (i.e., Cuenca-Carlino et al., 2016).

For the purpose of this review, we focused on published single subject, quasi-experimental, and group design intervention studies. We reviewed the abstracts of 287 studies to exclude articles that were duplicates, informational or non-experimental, or did not include an algebra outcome measure specifically. The search resulted in a total of 48 studies that were further evaluated to determine if each study met the inclusion criteria. We evaluated each study for inclusion based on the following criteria: (a) published in English in a peer-reviewed journal; (b) the study was conducted in the United States; (c) the study design was a group, quasi-experimental, or single-subject research; (d) the intervention focused on algebra; (e) the participants were middle school or high school students who were identified as having LD or were struggling with mathematics; (f) the study was conducted in a school setting. We included research that comprised other populations of students with disabilities if the results for students with LD or who were at risk of math difficulties were disaggregated.

A total of 11 single-subject and group-design studies met the inclusion criteria and were included in this review. Ives (2007) presented the results of two separate studies within one article. The information about different research components was explicitly stated for study 1. However, for study 2 Ives relied on the details and information presented for study 1. Therefore, study 2 was not included in the review.

Quality Indicators and Interrater Reliability

To evaluate the methodological rigor of the eleven included studies, we used CEC (2014) QIs for single subject and group design studies (see Table 1). CEC (2014) outlines a total of 28 QIs; 18 QIs are applicable to both single subject and group design studies. Six QIs are applicable only to group design studies and four QIs apply only to single subject design studies.

The CEC (2014) QIs are intended to be operationalized in such a way that two researchers, familiar with applying the QIs, should be able to independently code articles with acceptable reliability (Cook et al., 2015). Therefore, prior to coding, authors met to discuss the application of the QIs as they pertained to the specifics of this review (e.g., disability status of participants). A coding sheet created by the authors was used to rate each study. The authors coded and discussed several articles which did not meet the search criteria and were excluded from the review. Discrepancies in coding were resolved at that time until at least 90% agreement was reached. All studies were double coded with an overall inter-rater agreement of 100%.

Results

CEC's 28 QIs are divided into eight areas, which are discussed below. Of the 28 QIs, six apply specifically to group design research and four apply only to single subject research. The QIs were applied to the group design and single subject studies included in this review.

Table 1. ***Application of QIs to Reviewed Studies***

		Context/ Setting	Partici- pants		Inter- vention Agent		Descrip- tion of Practice		Implementa- tion Fidelity		
		1.1	2.1	2.2	3.1	3.2	4.1	4.2	5.1	5.2	5.3
Single Subject Design	Cuenca-Carlino, Freeman-Green, Stephenson, & Hauth (2016)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Maccini & Hughes (2000)	✓	✓	✓	✓	☒	✓	✓	✓	✓	✓
	Maccini & Ruhl, (2000)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Satsangi, Bouck, Taber-Doughty, & Bouck (2015)	✓	✓	✓	✓	☒	✓	✓	✓	✓	✓
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	☒	☒	✓	✓	✓	✓	✓
	Satsangi, Hammer & Hogan (2018)	✓	✓	✓	☒	☒	✓	✓	✓	✓	✓
	Scheuermann, Deshler, & Schumaker (2009)	✓	✓	✓	✓	☒	✓	✓	☒	✓	☒
	Strickland & Maccini (2012)	✓	✓	✓	✓	☒	✓	✓	✓	✓	✓
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	☒	☒	✓	✓	✓	✓	✓
Group Design	Ives (2007)	✓	✓	✓	✓	✓	✓	✓	☒	☒	☒
	Witzel (2005)	✓	✓	✓	✓	✓	✓	✓	✓	✓	☒
	Witzel, Mercer, & Miller (2003)	✓	✓	✓	✓	✓	✓	✓	✓	☒	✓

Table 1. ***Application of QIs to Reviewed Studies (continued)***

		Internal Validity								
		6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9
Single Subject Design	Cuenca-Carlino, Freeman-Green, Stephenson, & Hauth (2016)	✓	✓	✓	✓	✓	✓	✓		
	Maccini & Hughes (2000)	✓	✓	✓	✓	✓	✓	✓		
	Maccini & Ruhl, (2000)	✓	✓	✓	✓	✓	✓	✓		
	Satsangi, Bouck, Taber-Doughty, & Bouck (2015)	✓	✓	✓	✓	✓	✓	✓		
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	✓	✓	✓	✓		
	Satsangi, Hammer & Hogan (2018)	✓	✓	✓	✓	✓	✓	✓		
	Scheuermann, Deshler, & Schumaker (2009)	✓	✓	✓	✓	☒	✓	✓		
	Strickland & Maccini (2012)	✓	✓	✓	✓	✓	☒	✓		
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	✓	✓	✓	✓		
Group Design	Ives (2007)	✓	✓	☒	☒				☒	☒
	Witzel (2005)	✓	✓	✓	✓				☒	☒
	Witzel, Mercer, & Miller (2003)	✓	✓	✓	✓				☒	☒

Table 1. ***Application of QIs to Reviewed Studies (continued)***

		Outcome Measures/ Dependent Variables						Data Analysis		
		7.1	7.2	7.3	7.4	7.5	7.6	8.1	8.2	8.3
Single Subject Design	Cuenca-Carlino, Freeman-Green, Stephenson, & Hauth (2016)	✓	✓	✓	✓	✓			✓	
	Maccini & Hughes (2000)	✓	✓	✓	✓	✓			✓	
	Maccini & Ruhl, (2000)	✓	✓	✓	✓	✓			✓	
	Satsangi, Bouck, Taber-Doughty, & Bouck (2015)	✓	✓	✓	✓	✓			✓	
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	✓	✓			✓	
	Satsangi, Hammer & Hogan (2018)	✓	✓	✓	✓	✓			✓	
	Scheuermann, Deshler, & Schumaker (2009)	✓	✓	✓	☒	✓			✓	
	Strickland & Maccini (2012)	✓	✓	✓	☒	✓			☒	
	Satsangi, Hammer & Evmenova (2018)	✓	✓	✓	✓	✓			✓	
Group Design	Ives (2007)	✓	✓	✓	✓	☒	✓	✓		✓
	Witzel (2005)	✓	✓	✓	✓	☒	✓	✓		✓
	Witzel, Mercer, & Miller (2003)	✓	✓	✓	✓	✓	✓	✓		✓

Application of the QIs

Context and Setting

Only one QI falls under context and setting, which requires that the context/setting be reported in "sufficient detail" (p. 223) to determine that the setting is appropriate for purposes and outcomes of the study. All studies included in this review met this QI. Studies specified that they took place in middle schools (Cuenca-Carlino et al., 2016; Witzel, 2005; Witzel et al., 2003) or high schools (Satsangi et al., 2016; Satsangi, Hammer, & Evmenova, 2018; Satsangi, Hammer, & Hogan, 2018), or used the more general description, secondary school (Maccini & Hughes, 2000; Maccini & Ruhl, 2000). All eleven of these studies specified that the schools included populations of students with LD. Three studies took place in schools designed only for students with LD (Ives, 2007; Scheuermann et al., 2009; Strickland & Maccini, 2012). All of these settings were appropriate for research supporting algebra instruction for secondary students with LD.

Participants

Two QIs fall under the area of participants. To meet these QIs researchers must describe characteristics of participants that demonstrate the appropriateness of inclusion in the research (QI 2.1). QI 2.2 specifies that disability status must be reported for participants, along with how the disability status was determined. Cuenca-Carlino et al. (2016) specified that the six students involved in their research were identified as having LD with math-related IEP goals or were receiving intensive Tier 3 instruction. The remaining participants in the included research were identified as having LD by their school districts. All studies included in this research met both QIs in this area.

Intervention Agent

Two QIs also fall under the area of intervention agent. To meet the first QI in this area, researchers must specify the role of the intervention agent (QI 3.1). To meet the second QI, researchers are required to "describe specific training or qualifications (e.g., professional credential) required to implement the intervention, and indicates that the interventionist has achieved them" (p. 224). Cuenca-Carlino et al. (2016) specified that the interventionist was a "highly qualified math educator as determined by state licensure with a master's degree in special education," adding that the interventionist had five years of experience as the schools' primary teacher of Tier 2 math instruction (p. 77). Maccini and Ruhl (2000) described their interventionist as having "five years' experience teaching math to secondary students with mild disabilities in alternative and general placements" (p. 472). The teachers of record were trained to administer some of the interventions in their respective classrooms (Ives, 2007; Witzel; 2005; Witzel et al., 2003). Several studies, however, only specified that the interventionists were one of the researchers, but failed to describe the researcher's qualifications (Maccini & Hughes, 2000; Satsangi et al., 2016; Satsangi, Hammer, & Evmenova, 2018; Satsangi, Hammer, & Hogan, 2018; Scheuermann et al., 2009; Strickland & Maccini, 2012). Thus, while all studies met the criteria for QI 3.1, QI 3.2 was not met if researchers' qualifications were not described. A researcher who lacked background knowledge or experience in secondary math, and algebra specifically, would not automatically be qualified to deliver instruction in that area simply by holding a graduate degree in the broad area of special education. In order for teachers to teach algebra in most states, they must be highly qualified and licensed in the content area.

Description of Practice

To meet the two QIs that fall under the area of description of practice, researchers must provide adequate information about the intervention. Specifically, the researchers must describe the intervention procedures and the actions of the interventionist(s) (QI 4.1) and the materials required (QI 4.2). All 11 studies reviewed adequately described the intervention used in their research, as well as the materials involved. All interventions were based on the explicit instruction framework, except Ives (2007). In addition, interventions implemented strategies such as self-regulated strategy development (SRSD) and mnemonics (Cuenca-Carlino et al., 2016), the use of graphic organizers (Ives, 2007), and the use of concrete and virtual manipulatives (Satsangi et al., 2016; Satsangi, Hammer, & Evmenova, 2018; Satsangi, Hammer, & Hogan, 2018). Several studies implemented CRA (Maccini & Hughes, 2000; Maccini & Ruhl, 2000; Scheuermann et al., 2009; Strickland & Maccini, 2012; Witzel, 2005; Witzel et al., 2003). The reviewers felt that the provided descriptions of interventions and procedures would afford replication of each of the studies.

Implementation Fidelity

Three QIs fall under implementation fidelity. QI 5.1 requires that a checklist of critical elements of the intervention be assessed and reported. QI 5.2 entails reporting the duration and frequency of the intervention. QI 5.3 involves reporting fidelity across phases, interventionists, and settings (if applicable). Several of the articles reviewed carefully reported implementation fidelity to meet all three of these criteria (Cuenca-Carlino et al., 2016; Maccini & Hughes, 2000; Maccini & Ruhl, 2000; Satsangi et al., 2016; Satsangi, Hammer, & Evmenova, 2018; Satsangi, Hammer, & Hogan, 2018; Strickland & Maccini, 2012). While the duration and frequency of the research conducted by Scheuermann and colleagues (2009) was reported, thus meeting QI 5.2, no implementation procedures were listed or reported as assessed and implementation fidelity was not reported, thus failing to meet QIs 5.1 and 5.3. Witzel (2005) reported that a fidelity checklist was used and the duration of the intervention, meeting QIs 5.1 and 5.2. While he did specify that fidelity was checked across phases of the intervention, no fidelity data was reported (QI 5.3). On the other hand, Witzel et al. (2003) reported that a checklist was used (QI 5.1) across teachers (QI 5.3), but provided no information about how long the intervention lasted, thus failing to meet QI 5.2. Finally, Ives (2007) included no information on implementation fidelity, thus not meeting any of the QIs in this category.

Internal Validity

More QIs fall under the area of internal validity than in any other area. However, of the nine QIs considered in this area, three do not apply to single subject research, and three do not apply to group design research. In other words, both single subject and group design research must meet six QIs involving internal validity.

The first three QIs involving internal validity apply to all research. These involve controlling and systematically manipulating the independent variable (QI 6.1), describing baseline (for single subject) or control/comparison conditions (for group design; QI 6.2), and ensuring that participants in the baseline condition or those in the comparison group have no access to the intervention (QI 6.3). All reviewed studies met all three of these criteria, except for Ives (2007) who did not address how the treatment was limited to the control group (QI 6.3).

QIs 6.4, 6.8, and 6.9 must be met only by group design studies. These QIs involve reporting random or equitable assignment to conditions (QI 6.4), low overall attrition (QI 6.8), and attrition between groups (QI 6.9). Ives (2007) did not specify that the intervention and control groups were randomly assigned or functionally equivalent, thus failing to meet QI 6.4. None of the group design articles in this study met the requirements for attrition, failing both QIs 6.8 and 6.9. Ives (2007) and Witzel et al. (2003) did not report on attrition at all, and the inferred attrition rate for Witzel (2005) exceeds 30% and was not controlled for.

QIs 6.5, 6.6, and 6.7 apply only to single subject research designs. QI 6.5 requires at least three demonstrations of experimental effect at three different times. QI 6.6 mandates the use of a minimum of three baseline points that establish undesirable future performance. QI 6.7 requires that researchers control for threats to internal validity. Nearly all requirements for internal validity applied solely to single subject design were met by all included studies, with only two exceptions. In Scheuermann et al. (2009) three data points for experimental effect for instruction were not demonstrated for all participants (QI 6.5) and Strickland and Maccini (2012) included only two baseline data points for the study's first participant.

Outcome Measures/Dependent Variables

Six QIs are included in outcome measures and dependent variables. Of these, the first five apply to all research designs. The last QI applies only to group designs. QI 7.1 requires that outcomes are socially important. Dependent variables are clearly defined (QI 7.2). Effects are demonstrated through effect sizes for group designs and graphed data for single subject research (QI 7.3). Frequency and timing of outcomes are appropriate (QI 7.4). QI 7.5 requires that adequate internal reliability is reported for outcome measures. All reviewed studies met QIs 7.1, 7.2, and 7.3. QI 7.4 was not met by Strickland and Maccini (2012) and Scheuerman et al. (2009) because a minimum of three data points per phase were not demonstrated. Since teacher- or researcher-made tests were used solely as outcome measures for research conducted by Ives (2007) and Witzel (2005), neither of these studies could be deemed reliable (QI 7.5). Finally, QI 7.6, requiring adequate evidence of validity, is for group design studies only. All three group design studies met this criterion.

Data Analysis

Of the three QIs described in data analysis, two apply solely to group design studies, and one applies to single subject studies. QIs 8.1 and 8.3 apply to group design studies. These require that data analysis techniques used in each study are appropriate (QI 8.1) and that the study employs appropriate effect size statistics (QI 8.3). Both of these QIs were met by all three group design studies considered. QI 8.2, requiring a single subject graph representing outcome data for all study phases was met by all single subject studies included in this review, except for Strickland and Maccini (2012) who failed to include intervention points in their graph.

Most of the eight single subject research articles included in this review reported the percentage of nonoverlapping data points (PND). In the case of studies included in this review, PND is determined by counting the number of data points in the intervention phase that fall above the range of baseline points and dividing that number of points by the total number of data points in the intervention phase and multiplying this number by 100 (Gast, 2010). Maccini and Ruhl (2000) did not report effect size, but analysis indicates a 94.33 average PND across subjects. Maccini and Hughes (2000) did not report PND, and analysis of solution accuracy is difficult, due to very small graphs provided in the article, but accuracy of problem solution, averaged across students and operations is estimated to be 74.58%. All articles measured PND in terms of solution accuracy, except for Scheuermann et al. (2009) who assigned points for combined accuracy and the use of strategies across instructed and uninstructed problems. All reported PND were 100%.

All three group design studies included in the review reported means and standard deviations (Ives, 2007; Witzel, 2005; Witzel et al., 2003). However, only two of the three studies reported effect sizes (Ives, 2007; Witzel, 2005) which is the measure used to classify group design studies as having a positive, mixed/neutral, or negative effect (Cook et al., 2015). Witzel (2005) and Ives (2007) reported significant differences in treatment and comparison groups and effect sizes as being large.

Absolute and Weighted QI Coding

While Cook et al. (2015) in their description of the 2014 CEC QIs clearly quantify “28 total QIs” in eight different domains (p. 223), Royer et al. (2017) refer to the same QIs as “eight QIs” with “28 components” (p. 2). Royer et al. (2017) proposed using a weighted coding scheme, rather than an absolute system. They proposed that partial credit be given in each of the original eight domains of the 2014 QIs, or what they refer to as the eight QIs. For example, if one of the 9 components of QI 6 was missing or did not meet criteria, then the percentage of the components (8/9) would mean that the internal validity QI score was about 89%. Research would be deemed methodologically sound if all eight QIs received a score of 80% or better, when all components under each QI were considered. Royer et al. (2017) promoted the benefits of the weighted coding system as an alternative to “excluding studies of merit” and “offering insufficient recommendations to inform practice” (p. 3).

Lane et al. (2014) developed a QI matrix tool to determine if studies are methodologically sound using the weighted system, and ultimately, to determine if there is an evidence base for strategies, practices, or programs (available at ci3t.org). One requirement for establishing evidence-based practices, foundational to effective teaching, is that the research must be methodologically sound (Cook et al., 2012).

Table 2. ***Characteristics of Studies Included in the Review***

Citation	Intervention	No. of participants with disability or at risk	No. of participants without LD	Grade Level
Cuenca-Carlino et al. (2016)	Self-regulated strategy development (SRSD)	6	0	8
Ives, Study 1 (2007)	Visual representation	30	0	6-12
Maccini & Hughes (2000)	Problem solving strategy with CSA	6	0	9-12
Maccini & Ruhl (2000)	Problem solving strategy with CSA	3	0	8
Satsangi et al. (2016)	Virtual and concrete manipulatives	3	0	11 & 12
Satsangi, Hammer, & Hogan (2018)	Virtual manipulatives with explicit instruction	3	0	9
Satsangi, Hammer, & Evmenova (2018)	Virtual manipulatives with explicit instruction	3	0	9
Scheuermann et al. (2009)	Systematic instruction: CRA	14	0	6-8
Strickland & Maccini (2012)	Systematic instruction: CRA	3	0	8 & 9
Witzel et al. (2003)	Explicit Instruction Model with CRA	34	358	6
Witzel (2005)	CRA and a repeated abstract explicit instruction model	49	182	6-7

Table 2. ***Characteristics of Studies Included in the Review (continued)***

Citation	Design	Results
Cuenca-Carlino et al. (2016)	Multiple-probe-across-pairs	Students improved their ability to solve multi-step equations
Ives, Study 1 (2007)	Two-group comparison	Students in the experimental group improved their ability to solve linear equations
Maccini & Hughes (2000)	Multiple-probe across participants	Students' percent strategy use, percent accuracy on problem representation and solution improved
Maccini & Ruhl (2000)	Multiple-probe across participants	Students' percent strategy use and problem-solving skills involving integers improved
Satsangi et al. (2016)	Single-subject alternating treatment	Students' accuracy to solve single-variable linear equations improved
Satsangi, Hammer, & Hogan (2018)	Multiple-probe design across participants	Students' percent accuracy to solve multistep linear equations improved
Satsangi, Hammer, & Evmenova (2018)	Multiple-baseline design	Students' percent accuracy to solve multistep algebraic equations improved
Scheuermann et al. (2009)	Multiple-probe design across students design	Students' accuracy for instructed and uninstructed equations improved
Strickland & Maccini (2012)	Multiple-probe design across participants	Students' ability to multiply linear equations improved
Witzel et al. (2003)	Group-design	Students in the experimental group outperformed students in the control group
Witzel (2005)	Group design	Students in the experimental group outperformed students in the control group

Discussion

In the eleven studies included in this review, 41 students with disabilities participated in the eight single subject studies and 113 students with disabilities participated in the three group design studies. All participants ranged in age from 11 to 18 years, in grades 6 to 12. (See Table 2.) Research was conducted in general education classes and one-on-one or small group instruction settings. Types of problems included in the research were addition and subtraction of multivariable equations, single-variable equations, multi-step equations, word problems, and linear algebraic problems. Based on absolute coding standards originally recommended by Cook et al. (2015, p. 223), two single subject studies met all QIs. Four single subject studies failed to meet only one QI and two single subject studies failed to meet more than one QI. The three group design studies failed to meet three or more QIs (see graph for details). Interrater reliability for coding QIs met was 100%.

However, once the results of the coding were entered in Royer et al.'s (2017) QI matrix tool, nine out of 11 studies considered met criteria as an EBP using weighted coding; this includes the two studies which met criteria using absolute coding. Based on the weighted coding, only Ives (2007) and Strickland and Maccini (2012) failed to meet the criteria to be considered methodologically sound.

Evidence-Based Interventions

Interventions included in the research determined to be methodologically sound based on the weighted coding were explicit instruction framework paired with concrete, representational/semi-concrete and abstract (CRA/CSA) sequence of instruction (Maccini & Hughes, 2000; Maccini & Ruhl, 2000; Scheuermann et al., 2009; Strickland & Maccini, 2012; Witzel, 2005; Witzel et al., 2003), virtual manipulatives (Satsangi et al., 2016; Satsangi, Hammer, & Evmenova, 2018; Satsangi, Hammer, & Hogan, 2018), and self-regulated strategy development (SRSD) paired with graphic organizer and mnemonics (Cuenca-Carlino et al., 2016). All effect sizes were strong.

Limitations

There are several limitations associated with our findings. Even though we were able to use the same QIs for both single subject and group designs, it is difficult to compare the effectiveness of single subject and group designs. This factor also makes comparison of the effectiveness of strategies difficult. In addition, studies included a mix of general education students and students with LD, as well as students with other disabilities. If researchers do not present disaggregated results for students with LD, it is difficult to determine the effect for this population. Also, although the CEC QIs are better operationally defined, they are still subject to interpretation. Cook et al. (2014) stated that "reviewers might sometimes need to use their informed judgment to determine when a quality indicator has been met" (p. 207). For example, does holding a doctoral degree in special education mean someone is automatically qualified to deliver instruction at high school level? Furthermore, the research conducted prior to the publication of the CEC QIs in 2014 obviously did not have the QIs to reference, which may put those studies at a disadvantage. Finally, this review included only published studies. A future review may want to include dissertations.

Implications for Research and Practice

Results of the current review identify a number of emerging implications for researchers and practitioners. Since there is a paucity of research, more replication and extension of studies is needed to establish a pool of strategies for algebra instruction for secondary students with LD, especially group-design studies. Since several strategies were found to be effective paired with the application of the explicit instruction framework, bundling of strategies would help to strengthen the intervention for algebra instruction. Researchers who did bundle strategies, such as Cuenca-Carlino et al. (2016) who combined strategies such as use of mnemonics and graphic organizers, and Satsangi, Hammer, and Hogan (2018), who paired the use of virtual manipulatives with explicit instruction, found these combined strategies to be effective.

Practitioners can effectively use these combined strategies to help students conceptualize algebra and other math concepts. CRA/CSA involves the use of a sequence of instruction using concrete or virtual manipulatives, then pictures or schematic diagrams, including graphic organizers, alongside the mathematical symbols or equations. Mnemonics can be used as a cognitive strategy aid to enhance procedural fluency. Both the explicit instruction framework and self-regulated strategy development (SRSD) include a set of steps that provide a framework for teaching; these include teacher modeling and guided and independent practice. The explicit instruction framework and SRSD can be used to teach any mathematical concept. It differs from explicit instruction framework in part due to the emphasis on memorization of a strategy that provides additional scaffolding for students.

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