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A Qualitative Synthesis of Algebra Intervention Research

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Abstract

Completion of a quality Algebra course by 8th grade is a prerequisite for successful entry into STEM majors; thus best practices in this critical course must be as equitable as possible to support STEM recruitment and retention. However, if the research base for Algebra is under-examines some populations of students, structural inequity may be unintentionally built into evidence-based practices. The purpose of this synthesis is to examine the ways in which qualitative Algebra strategy research did –or did not- account for equity issues including gender, SES, rural students, special education status, ethnicity, and native language through theoretical and participant choices. This synthesis used qualitative research integration techniques to provide a summary of fifty-eight qualitative investigations of Algebra 1 teaching strategies. The majority of studies specified constructivism, social constructivism, and situated cognition theoretical frameworks or did not specify a theoretical framework. The majority of research questions addressed the effectiveness of a particular pedagogical technique or intervention. Results suggest that the majority of study participants were Caucasian students from suburban localities and did not include sufficient detail necessary for replication.

Introduction

Access to, and completion of, a quality Algebra course by eighth grade is positively linked with success in higher-level mathematics courses, admission to college, and entry into STEM majors. Successful completion of an Algebra course is a prerequisite for entry into all STEM fields (Bottia, Stearns, Mickelson, Moller, & Parker, 2015; Gilmer, 2007; Maltese & Tai, 2011; Riegle-Crumb, King, Grodsky, & Muller, 2012). Furthermore, for students who declare an initial STEM major, they are most likely to leave the field after taking introductory calculus, and poor Algebra skills are the third most likely reason for a student to struggle in calculus (Rasmussen, Ellis, Zazkis, & Bressoud, 2014; Rasmussen & Ellis, 2013).

Since Algebra I is a critical prerequisite for STEM majors, it is important to all STEM educators that the research supporting best practices be as equitable as possible. Any achievement or access gaps between groups of students in Algebra I hinder access to advance mathematics study in high school and college admission (Hott & Carlson, 2017). These gaps in Algebra access and achievement will confound recruitment and retention of students in other STEM areas because the Algebra gaps have shrunk the pool of possible candidates (Mau, 2016).

To address the needs of students struggling to master mathematics content, both mathematics education and special education researchers have devoted much attention to quality Algebra instruction. One way to summarize study outcomes is through research synthesis. Research syntheses provide a means of systematically summarizing a large body of research (Scruggs et al., 2006). Within special education research syntheses have largely focused on group-experimental and single case studies using meta-analytic techniques to report math intervention outcomes. Several meta-analyses have synthesized mathematics interventions for students with learning disabilities (see Gersten et al., 2009; Marita & Hord, 2017), students with emotional and behavioral disorders (Templeton, Neel, & Blood, 2008), students with cognitive disabilities (Browder et al., 2008), and students who are "low achieving" (Baker, Gersten, & Lee, 2002). Findings suggest that a variety of self-management, schema-based, computer assisted instruction, and mnemonic strategies are beneficial. Further, explicit and direct instruction methods have increased the mathematics performance of students with disabilities.

Although, we have learned much about what constitutes quality mathematics instruction and intervention, little attention has been paid to the qualitative foundation of these large scale studies. Qualitative studies, used for hypothesis generation for larger scale studies, form the basis for our understanding of what effective Algebra instruction is. If there are gaps in the qualitative foundation, the quantitative achievement studies' results are less generalizable. Such gaps in the research could lead to structural problems in how problems are presented to students, which in turn could codify the achievement gaps within the research-based best practices for Algebra instruction (Boaler, 2002). For example, the work of TODOS, an organization committed to language diversity and quality mathematics instruction, reports that the mathematics literature has focused almost exclusively on students who speak English as there home language; ignoring significant numbers of students. The following research question guided our work: To what extent does qualitative Algebra strategy research account for equity issues including gender, SES, rural students, special education status, ethnicity, and native language?

To develop an understanding of the perspectives of mathematics and special education researchers on Algebra I, we completed a qualitative synthesis. Unlike quantitative syntheses focused on deriving an effect size, qualitative syntheses focus on integrating themes and insights from individual investigations to understand the body of research while preserving the integrity of individual reports. We choose to complete a qualitative synthesis as the majority of work completed within mathematics education employ qualitative methods, recent requests for qualitative syntheses in mathematics education (Thunder & Berry III, 2016), increasing qualitative investigations within special education (Scruggs, Mastropieri, & McDuffie, 2006), and a recent call for the use of qualitative methods to develop an understanding of the nuances of interventions (Fuchs & Fuchs, 2017). Like previous qualitative syntheses conducted in special education (see Erwin, Brotherson, & Summers, 2011; Scruggs, Mastropieri, & McDuffie, 2007), we choose to treat each report as an "individual informant"; thus, original data is preserved and data can then be synthesized across studies.

We choose to analyze the theoretical frameworks that mathematics and special education researchers approached problems to better understand the lens through which the current corpus of research questions have been asked. We also worked to ensure that we had understanding of the context in which the research was conducted. For example, although rural students make up over 19% of school-aged children, they are often left out of the mathematics literature base (Feinberg, Nuijens, & Canter, 2005). If we can better understand the work of our colleagues, we are more likely to be able to use the research base to effectively meet the needs of practitioners and policy makers.

Method

Our research team included both practitioners and researchers focused on meeting the mathematics needs of learners with exceptionalities. We sought to gain an understanding of the theories, types of questions mathematics education and special education researchers, the conditions under which investigations are completed including study settings and participants involved in completing Algebra studies us qualitative synthesis techniques.

Search Procedures

Due to the differences in terminology used across disciplines, we included any investigation that involved a strategy, intervention, or instructional technique with the goal of improving Algebra instruction in the synthesis. Research assistants completed searches of ERIC, PsychINFO, ProQuest, and JSTOR using various combinations of intervention, strategy, Algebra, math, mathematics, learning disability, and disability. Two assistants independently completed searches and recorded references using an Excel document. Copies of articles that met the aforementioned study inclusion criteria were uploaded to a DropBox® file so that articles could be accessed by all members of the research team.

Next, ancestral searches of reference lists and a descendant search of cited research using the Social Sciences Citation Index to identify reports that cited relevant research were completed. Finally, hand searches of prominent special education (e.g., *Exceptional Children*, *Journal of Special Education*, *Exceptionality*, *Learning Disabilities Research and Practice*, *Remedial and Special Education*, *Learning Disabilities Quarterly*, *Teacher Education and Special Education*) and mathematics education (e.g., *Education Studies in Mathematics*, *Journal for Research in Mathematics Education*, *For the Learning of Mathematics*, *The Journal of Mathematics Teacher Education*, *Mathematical Thinking & Learning*, *ZDM*) journals were completed. In keeping with previous qualitative syntheses in special education, we did not set date parameters. However, studies included were published between 1981-2016.

Data Analysis

To understand the questions and conditions under which Algebra studies have been conducted, the research team collaboratively developed coding conventions and a protocol including theory, study purpose, research questions, setting, and participants. After all relevant reports were collected and organized in a common digital file, each member of the research team read each report at least once. We then completed a quality check using the "credibility or trustworthiness" criteria developed by Bratlinger et al., (2005). We included all reports that met a minimum standard of quality and went though some form of peer review (i.e., dissertation or thesis committee, editorial board, conference chair). During initial reading, we individually took notes and recorded comments. Then we collaboratively developed a process for open coding. First, theory, purpose, and research questions were coded. Next, demographic variables were coded. Each report was independently coded by two members of the research team, discussed with the entire research team to resolve any discrepancies, and recorded in the team database. The process was recursive in that we continuously revised coding decisions to support consistent and systematic coding.

Results and Discussion

Search results yielded 69 articles and dissertations that involved interventions, strategies, or techniques to improve Algebra instruction. Five dissertations were excluded as a peer-reviewed article was published based on the work. In all, 58 studies that met over 60% of Brantlinger et al.'s (2005) quality and relevance criteria in the synthesis. Inclusion and quality inter-rater reliability was 100%.

Theoretical Perspective

A theoretical stance was reported in 38 (66%) of the 58 investigations. Reports published in mathematics education journals were more likely to include a theoretical framework than reports published in special education or teacher education journals. Of the 31 reports published in mathematics education journals, mathematics conference proceedings, or dissertations completed within mathematics education departments, 19 (61.5%) included a theoretical perspective.

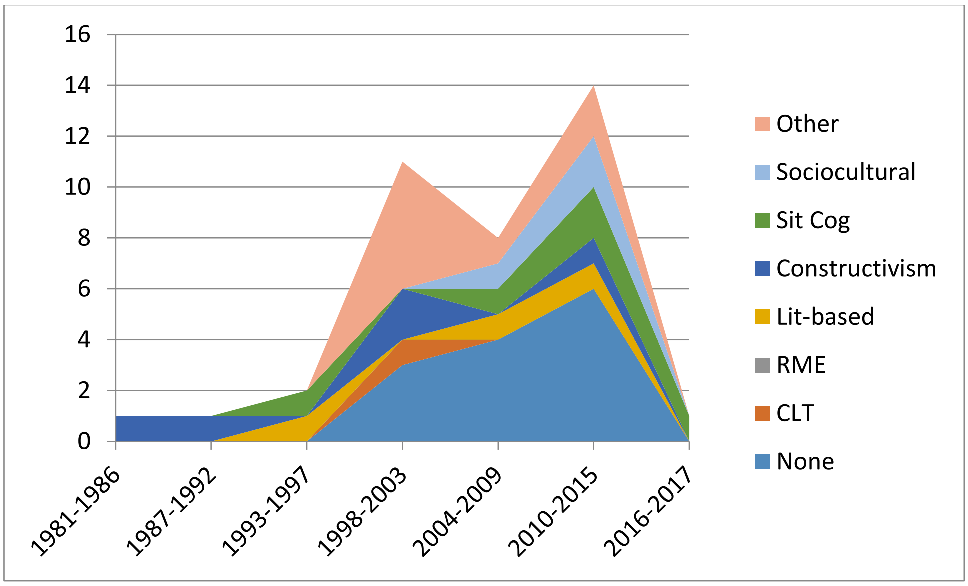

Figure 1. Mathematics Education Theoretical Perspectives

Prior to 2002, there were fewer qualitative studies published in mathematics education. Even the earliest study (Wagner, 1981) used an explicit theoretical perspective, but theoretical perspectives are not consistently used until 2010. Post 2002, the theoretical perspectives were most commonly not reported, situated cognition, or social constructivism. While there was increased theoretical diversity in the past five years, neither realistic mathematics education (RME) nor any critical theoretical perspectives have been used in any of the studies.

Only 6, (34%) of the studies published in special education or teacher education journals included a theoretical framework. The majority of studies specified constructivism, social constructivism, or situated cognition theoretical frameworks. The remaining studies used realistic mathematics education, structuralism, or other theoretical perspectives that were derived from the coding of a previously cited article. None of the reports that met the inclusion criteria that utilized critical theoretical frameworks, but both of the studied framed using RME reported positive outcomes for students' Algebra learning, including students with severe disabilities.

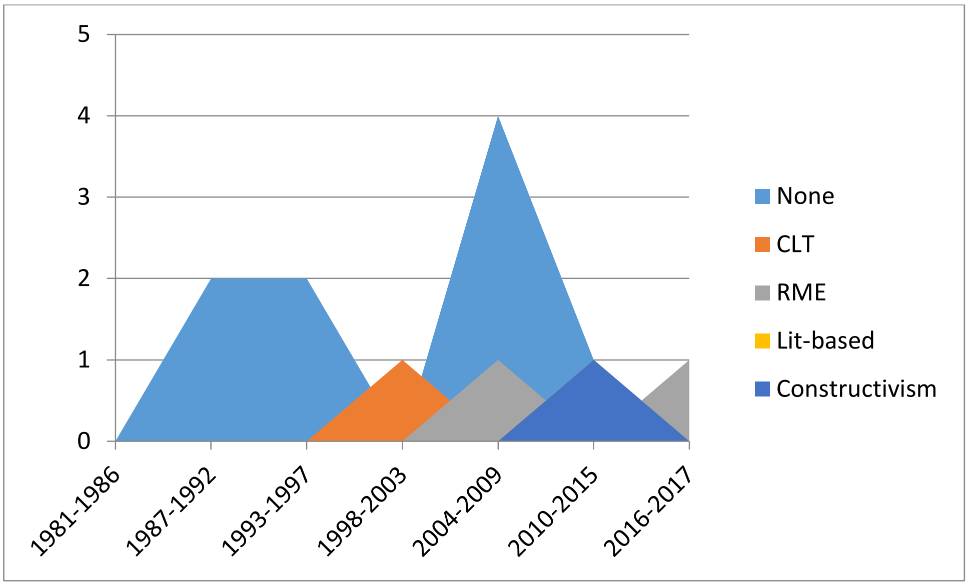

Figure 2. Special Education Theoretical Perspectives

Research Questions

Reports published in mathematics education, special education, and teacher education journals included similar questions. The majority of questions focused on instructional methods such as problem based learning, inquiry based instruction, and explicit instruction. Open coding the research questions revealed 11 categories, which are summarized in Table1.

Table 1. Sample Research Questions

Category	**Sample**
Problem Solving	What strategies and representations do students use when solving problems?
Technology	Which types of instrumental orchestration emerge in technology-rich classroom teaching?
Curriculum	We will examine how the combination of the task setting and the spreadsheet environment offered opportunities for pupils to move expressions of generality, and to give meaning to the manipulation of these expressions.
Discourse	To what extent do teacher and student discourse about math content reflect similar knowledge structures?
Students' Learning	To what extent did giving students an opportunity to choose their own type of assignment in Algebra 1 increase student motivation to learn and positively affect content mastery?
Engagement	In what ways might students' engagement in representational practice support further mathematics learning?
Instruction Method	Do students in the function-based group demonstrate a deeper relational understanding of simplifying expressions than do those in the traditional Algebra group?
Prior Knowledge	Second, in what ways does prior knowledge of Algebra impact students' flexible use of solution methods?
Testing	How are the EOC exam for Algebra I scores from students in the 10 Algebra I classes related to differing instructional practices?
Academic Ability	What adaptions or accommodations do teachers use to differentiate teaching and learning activities to meet diverse student needs?
Pedagogy	Does our bridging pedagogy help students to better learn letter-symbolic Algebra?

In mathematics education, the most common questions were intervention-based. Typically, these questions were combined with an additional question on student perceptions of the intervention, or with a quantitative question measuring achievement gains in a pretest/posttest design over the intervention unit. There are two small spikes in qualitative Algebra I research that coincide with the passage of NCLB and the adoption of the common core. During this time period, students' discussions, transition to Algebra, and problem solving through Algebra emerged as common supplementary questions to intervention studies (Figure 3). There were no specific research questions investigating the learning of underrepresented student groups. Although it is possible that such students were purposely recruited into studies the sparse data on participant descriptions prevent us from drawing conclusions that such recruitment occurred.

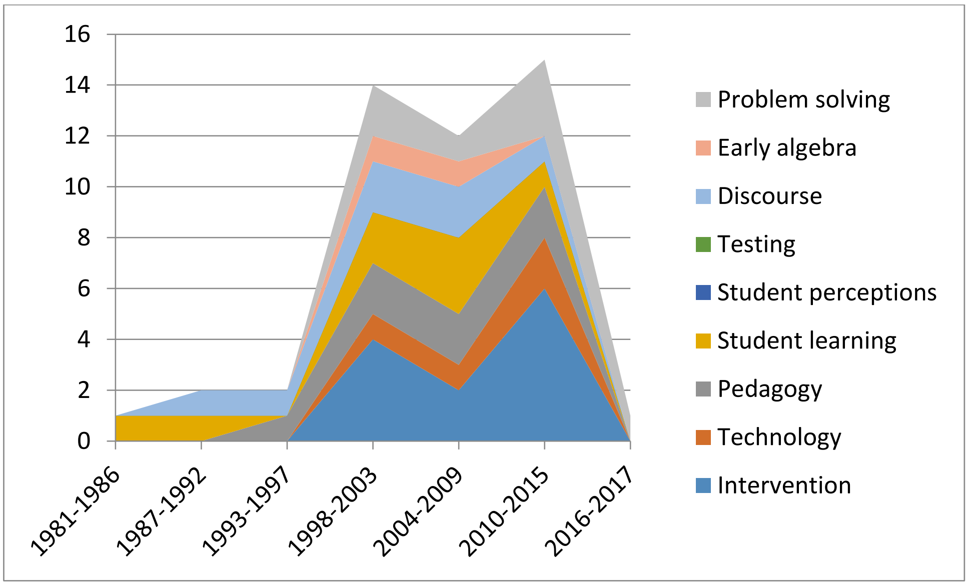

Figure 3. Mathematics Education Research Questions

In special education, qualitative research questions were embedded in mixed method studies until 2011. The quantitative questions were typically single case research designs, so the intervention and student perception questions were extensions of a single case social validity check. Although technology use has been a minor but consistent topic of research in qualitative Algebra I studies in mathematics education, technology was not a topic in qualitative special education research until after the passage of NCLB (Figure 4). There were no specific research questions investigating the learning of any specific underrepresented groups in Algebra I research, though participants were all students with mathematics disability or difficulty.

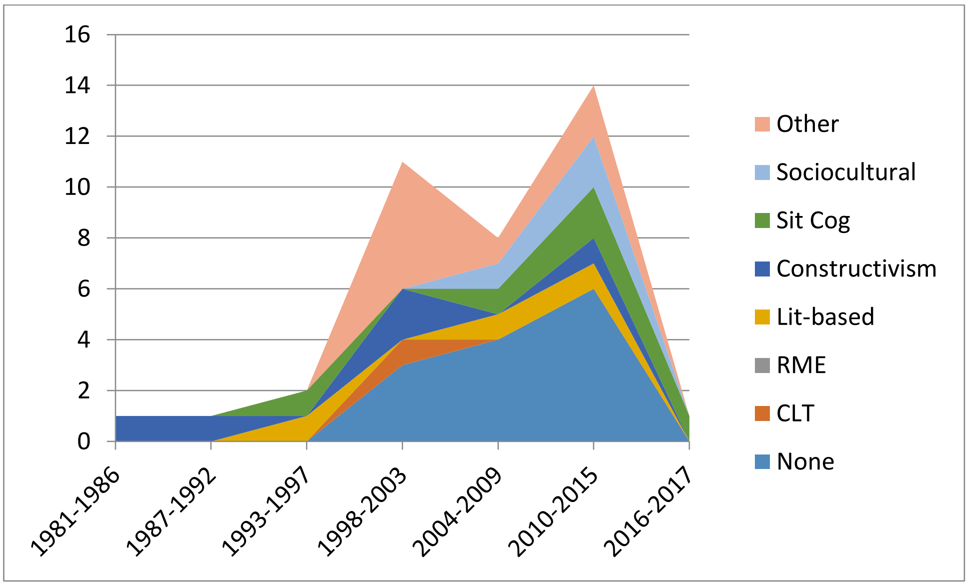

Figure 4. Special Education Research Questions

Setting

Overall, the setting descriptions were relatively scant (Table 2). In mathematics education, the only setting characteristic reported more than 50% of the time was whether the district was in an urban, suburban, or rural locality (56%); whereas the only characteristic that special education reported over 50% of the time was the geographic region in which the study occurred (77%). A significant portion of the schools at which the studies took place were suburban (14%), with little attention paid to rural districts (5%), but the large amount of unreported school type data (70%) makes it difficult to draw conclusions.

Table 2. Percentage of Reports Including Setting Variables by Discipline

	Mathematics Education	Special Education
Public/Private/Charter	29%	8%
Geographic Region	44%	77%
Grade Level	40%	31%
School Size	16%	38%
Urban/Suburban/Rural	56%	31%

The description of study setting was a median length of two sentences (range = 0-5) per report. The typical setting description included minimal demographic information such as the percentage of students receiving free and reduced lunch and ethnicity. Studies reported a variety of characteristics including geographical region, locality (rural, suburban, urban), or type (public, private, charter) but they majority did not go into detail significant enough to understand the conditions under which the strategy was implemented. However, a few studies provided descriptions that reported sufficient detail to understanding the study setting:

> The participants were from a large area high school with a total enrollment of approximately 2200. The district is located in a rapidly-growing suburb o f a major metropolitan area… The site high school was on a block schedule, and students met each of their classes for 90 minutes every other day. Lab sections met on the alternate days so that these students had mathematics every day. Students in the lab sections were graded on a pass/fail basis and received a local credit (not a mathematics credit) Brawner, 2001.

The following table summarizes the types of setting variables reported by each study. The categories in the table were the six levels of setting descriptions reported by any study. No study reported all six levels of setting description, though three studies did report five. Region and school type were the most commonly missing setting variables, though the grade level of the classroom studied was omitted from the school level description or given as participant description information. A study was credited with reporting grade level data in classroom description if it appeared anywhere in the setting description. Still, it is not always clear if the schools studied were high schools, middle schools, or elementary schools, much less if the participants were performing at or above grade level. However, the skew in reported data in 9^{th} grade and below suggests that these participants were likely performing at least on grade level.

Participants

The description of participants was a median length of two sentences (range = 0-7). Typically, grade level was reported and several studies included ethnicity and gender of the school population but not of the sample studied. The majority of studies that did specify participants were completed in suburban classrooms with Caucasian participants. Although, the majority of descriptions did not include sufficient detail to understand participants, a few studies included descriptions that provided an overall picture of the school population but less information about individual participants. For example, Kortering, McClannon, and Brazil (2008) report:

> In high School A an estimated 12% of students were African American; 4% were Hispanic, non-Latino; and 4% were Asian, including Hmong. At High School B, 6% of students were in ethnic minorities (African American and Hispanic, non-Latino). The schools had 36% and 11% of their students receiving free or reduced-price lunches during the 2002 to 2003 school year, rates that may be underestimates of actual poverty rates in that eligible adolescents often fail to request lunch assistance once they enter high school.

Table 3. Summary of Setting Variables by Study

Study	Country	Region/ State	School Type	Location	School Description	Classroom Description
Al-Murani (2006)	---	---	Private	Suburban	K-8	---
Baxter et al. (2005)	USA	Pacific Northwest	---	---	Middle school	7th grade
Baxter et al. (2001)	USA	Pacific Northwest	---	Suburban & Medium sized city	Two elementary schools	7th grade
Beatty & Bruce (2012)	---	---	---	---	Two schools	7th and 8th grade
Bills et al. (2006)	---	---	---	---	Two secondary schools	---
Boaler (1998)	United Kingdom	---	---	---	---	---
Boaler (2002)	---	---	---	---	---	---
Boaler & Staples (2008)	---	---	---	Urban, Rural, Coastal	Three high schools	25-35 students per class
Borasi & Rose (1989)	---	---	---	Not selective, parental choice	One content-based and one process-based school	---
Brawner (2001)	---	---	Public	Suburban	High school	At-risk 9th graders
Brodie (2010)	South Africa	---	---	---	Well resourced	9th grade
Carpenter et al. (1998)	---	---	---	One rural school, two unspecified schools	---	1st, 2nd, 3rd grade
Carraher et al. (2006)	USA	Greater Boston area	---	Multi-ethnic community	---	Grades 2-4
Cayton (2012)	USA	North Carolina	Public	Rural	Four high schools with 1:1 laptop initiatives	---
Chazan (1999)	USA	North East	Jewish Private	---	---	9th grade
Chiu (2004)	---	---	Public	Large Urban	---	---
Cobb et al. (1997)	---	---	---	---	---	1st grade
Dahlstanl (2004)	---	---	---	---	---	---
Drijvers et al. (2010)	Belgrain and Dutch Schools	---	---	---	---	8th grade
Earnest (2015)	USA	Northern California	Charter, Public, Private	---	---	Grades 5, 8
Eisenman & Chamberlin (2001)	---	---	---	---	Vocational schools, comprehensive high schools, alternative school for students with behavior problems	---
Falkner et al. (1999)	---	---	---	---	---	Grades 1, 2
Fletcher et al. (2010)	---	---	---	---	Middle school	Self-contained classroom

Godfrey (2011)	---	---	---	---	Gifted and talented elementary school	8th grade
Haines (1996)	Western Australia	Perth	---	---	Secondary school	9th grade
Hallagan (2006)	USA	North east	---	Urban	Middle school	---
Herscovics & Linchevski (1991)	Canada	Montreal	Parochial	---	---	7th grade
Huang et al. (2005)	USA	New Jersey	Private	---	High school	---
Huntley et al. (2008)	USA	Midwest, West	---	---	---	---
Kieran (2001)	Canada	Montreal	Private	---	High school	---
Kortering et al. (2007)	USA	South east	---	---	High school	---
Kortering et al. (2009)	USA	North Carolina	---	---	High school	12-30 students per class
Kratofil (2014)	---	---	---	---	---	---
Lange (2014)	USA	Southwest Virginia	Public	Suburban	---	---
Looi & Lim (2009)	Singapore	---	---	---	---	---
Lowery (2003)	USA	Northern Virginia	Public	Suburban	Three EXCEL high schools (lowest performing schools in district)	---
Lynch (2011)	USA	West Virginia	---	---	High schools	---
Lynch, K., & Star (2013)	USA	New England	---	---	Ten middle and high schools	---
Malloy and Malloy (1998)	USA	North Carolina	Public	Rural, suburban	High schools	---
McClure (1999)	USA	North Central Texas	---	Urban, suburban	---	---
Moschkovich (2004)	---	---	---	---	---	---
Newton et al. (2010)	---	---	---	---	High school	Grades 9, 10, 11
Radford et al. (2007)	Canada	Ontario	---	---	---	---
Riggs (2001)	USA	North Central Texas	---	---	High school	9th grade
Rodriguez (2016)	USA	New Mexico	---	---	---	Individuals with intellectual disabilities ages 22-45
Sagaskie (2014)	USA	Midwestern	---	---	---	9th grade
Selling (2016)	---	---	---	---	---	Grades 6, 7
Smith (2001)	---	---	---	Urban	High schools	---
Staats (2016)	---	---	---	---	College	undergraduates
Stacey et al. (2008)	---	---	---	---	Secondary schools	---
Swafford et al. (2000)	USA	Midwestern	---	Town	---	---
Sylva (2014)	---	---	Parochial	---	---	Grades K-12
Throne (2012)	USA	Northern California	Unified School Districts	---	---	---
Wagner (1981)	USA	Bronx/Manhattan	Public, private	---	Middle and high schools	---
Walkington et al. (2013)	USA	Texas	---	Urban	High school	---
Wohlgehagen (1992)	USA	North Central Texas	---	Suburban	High school	9th grade
Yerushalmy (2006)	---	---	---	---	---	Grades 8, 9

Note: --- = information not provided

A more typical description is provided Kratofil (2013), "The demographics of the study participants reflected the overall demographics of the school with 95% white and 15.7% free and reduced lunch". Table 4 provides a summary of participant demographics. Most mathematics education studies reported the grade or the grade and gender of the participants but no other information. Both mathematics and special education reported IEP status, ethnicity, gender, native language, and SES rarely, which makes it impossible to evaluate how often underrepresented groups have been studied. Furthermore, half of the time that these participant characteristics were reported, they indicated that participants were white, medium to high SES.

Table 4. Percentage of Reports Including Student Level Demographic Variables by Discipline

	Mathematics Education	Special Education
IEP	24%	38%
Ethnicity	11%	15%
Gender	29%	23%
Grade	80%	38%
Native Language	2%	0%
SES	7%	8%

Conclusion

Overall, it is difficult to determine who is being researched in Algebra studies due to the relatively few articles reporting rich setting and participant descriptions. Grade level alone is insufficient to understand the conditions under which strategies are implemented. The majority of study participants attended predominately suburban schools and included Caucasian students not eligible for free and reduced lunch. These practices suggest that current reports do not accurately represent the students attending our schools and that female students, students of color, students with disabilities, and students outside of the well-funded suburban districts may not be included in the Algebra literature base.

In addition to scant setting and participant description, many studies did not provide a theoretical perspective. Theoretical perspectives should be reported in research studies to provide readers with an understanding of how the study was constructed. Ideally, such perspectives are described in more than a single paragraph and linked to the research questions and analyses. Although realistic mathematics education (RME) has been a relatively popular theoretical perspective in undergraduate mathematics education (Gravemeijer & Doorman, 1999; Trenholm, Alcock, & Robinson, 2016), there were no Algebra studies employing RME as a theoretical perspective. Documenting a theoretical perspective may assist with enhancing communication across disciplines. As mathematics and special education researchers, there are several directions for inquiry in Algebra. More research is needed using Algebra in context, possibly with a realistic mathematics education lens. Critical gender and critical race theory may be beneficial in developing a more comprehensive understanding of Algebra strategies. Meta-theoretic frameworks such as the How People Learn (HPL) framework may also be useful lenses for further Algebra I inquiry (Melnikova, 2015).

Interestingly, the questions posed by mathematics and special education researchers involved similar phenomenon. This illustrates aligned goals including exploring strategies to meet the needs of all students, including students with mathematics difficulty or disability. Because similar questions are posed, it may be beneficial to collaboratively address areas of identified need.

Recommendations

Algebra inquiry needs to widen beyond perception of being either a course for mathematically gifted students in middle school or something most students naturally learn in early high school. Use of a quality rubric, such as Bratlinger et al. (2005), may assist researchers with disseminating findings to a larger research community and with providing sufficient detail to support understanding what interventions under what conditions, for what children work to meet the needs of students, including students with mathematics difficulty or disability. In order to begin to patch the pipeline to the rest of STEM education, mathematics educators must deepen and broaden the body of Algebra I research to include representative samples of participants in both quantitative and qualitative inquiry.

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