Critical Appraisal of Mathematics Education Systematic Review Search Methods: Implications for Social Sciences Librarians

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Social sciences librarians have an interest in supporting systematic reviews, but the available guidance is focused on health sciences settings. This study contributes guidance specifically for social sciences librarians using the Campbell Collaboration's standards to evaluate the search methods reported in systematic reviews on K–12 mathematics education. After searching ERIC (EBSCO), Education Source (EBSCO), Academic Search Ultimate (EBSCO), and Compendex (Engineering Village) in April 2018, we included 40 systematic reviews. The reviews were evaluated on the transparency of the reporting and the comprehensiveness of the search as required by the standards. The findings revealed deficiencies in search processes and reporting of search methods. We conclude by discussing the implications of these findings for librarians collaborating with social sciences researchers.

Introduction

Social sciences librarians have a valuable skill set for collaborating with researchers to develop search protocols for a research synthesis. This skill set includes knowledge of subject database coverage and interface features and experience developing and refining search strategies in support of research questions. Research synthesis methods, which analyze studies on a particular topic, have been used and debated within the education discipline.[1] The systematic review method is a research synthesis method in which a group of studies matching a predefined set of criteria are collected and appraised to answer a research question. The procedures for conducting a review can be summarized in four steps.[2] The first step is planning the review, including framing the research question, defining the eligibility criteria, and determining project management issues such as software, timelines, and target outputs. The second step is identifying the studies through determining resources to be searched, conducting the search, removing duplicates, and documenting the search. The third step is evaluating the citations collected to select those that match the eligibility criteria. The fourth step is coding and appraising each study with a fully described and transparent process. While a meta-analysis often uses

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systematic review search procedures to locate and select studies, meta-analysis is a statistical technique used to combine data from multiple studies. The use of systematic review methods in education gained popularity in the early 2000s due to pressure to use research evidence of what works when developing policy and practice.[3] The increasing number of systematic reviews and meta-analyses published in the education discipline during the last five years illustrates that these methods are widely used research synthesis methods.[4]

What Works Clearinghouse from the Institute of Education Sciences, the Campbell Collaboration, and the Evidence for Policy and Practice Information and Coordinating Centre are the three primary groups that support the development of systematic reviews focused on social sciences, including education.[5] The Campbell Collaboration aligns its work with what the Cochrane Collaboration did for systematic reviews in the medical sciences and provides the most detailed guidance for conducting and reporting systematic reviews on social interventions in the *Methodological Expectations of Campbell Collaboration Intervention Reports (MECCIR)*.[6] The MECCIR standards were first adopted in October 2014 and subsequently updated in May 2017.[7]

The quality of a systematic review or meta-analysis depends on the appropriateness of the search methods, which can only be adequately evaluated if the search methods are transparently reported. This study uses the Campbell Collaboration standards to evaluate the quality of the search methods reported in systematic reviews and meta-analyses on kindergarten through twelfth grades (K–12) mathematics education interventions. The topic was chosen to reflect the Campbell Collaboration's focus on intervention reports and to focus on the education discipline. This study is important because no study has evaluated the reported search methods using the MECCIR guidelines, which we believe provide an aspirational standard for reporting. Additionally, this study evaluates search methods from a librarian perspective, which highlights the areas where librarians can use their valuable skill set when collaborating with social sciences researchers. The following research questions guided our study:

- Are the search methods reported by mathematics education researchers following the MECCIR standards for conducting and reporting systematic reviews?
- What are the implications for librarians collaborating with social sciences researchers conducting systematic reviews?

Literature Review

Librarians and Systematic Reviews

There is increasing interest from social sciences librarians in learning to support systematic reviews. In 2017, the Association of College and Research Libraries' (ACRL) Education and Behavioral Sciences Section (EBSS) sponsored a webinar about systematic reviews, and the EBSS Higher Education Committee published an article in the EBSS Newsletter describing systematic reviews for social sciences librarians.[8] In 2018, an ACRL Systematic Reviews Interest Group was created for librarians supporting systematic reviews outside the health sciences. Additionally, recent articles provide librarians outside health sciences with resources about systematic reviews[9] and with an example of how to implement a systematic review service.[10]

Despite the increased interest in supporting systematic reviews, there is little guidance in the library and information science (LIS) literature for social sciences librarians collaborating with researchers conducting systematic reviews. The role of the librarian in systematic reviews in the health and medical sciences libraries has been widely studied, but the librarian's role has been

discussed rarely outside those contexts.[11] Sheble argues that librarians in more diverse types of libraries need to explore how research synthesis methods can be used.[12] Even in academic library journals, articles about librarian support of systematic reviews describe health sciences settings.[13]

The limited studies that examined systematic reviews outside the health sciences have looked at search methods;[14] systematic review support resources;[15] the relationship between evidence-based practice, systematic reviews, and education faculty;[16] and a librarian's experience on a systematic review team.[17] Arendt was one of the first authors in LIS to analyze the search process in published meta-analyses outside health sciences.[18] Focusing on meta-analyses published in psychology, Arendt found inconsistencies in the application of search strategies and the reporting of the search strategy.[19] Using the topic of workplace e-learning, Papaioannou, Sutton, Carroll, Booth, and Wong found that, for multidisciplinary social sciences topics, multiple types of search strategies need to be used to account for the dispersed nature of the literature.[20] Another article described the steps for developing a systematic review search in the social sciences.[21]

Previous Research on Evaluation of Systematic Review Searches

While only a few articles in LIS have evaluated the search strategies for systematic reviews in social sciences,[22] multiple studies published in the education literature have evaluated systematic review methods.[23] Studies that have evaluated the procedures for conducting systematic reviews related to education have consistently identified a number of areas for improvement in regard to the search process. One area noted in several studies is the need to search multiple types of sources. Borrego, Foster, and Froyd found that researchers did not search different sources of information.[24] Torgerson advocates that authors should more directly address publication bias and its potential effects on results.[25] In an examination of the methodological characteristics of overviews, which are systematic reviews that only include systematic reviews, the names of online databases were typically reported, but "other critical aspects of the search, such as reference harvesting (48%), author contacting (16%), and hand searching (40%), were reported less than half the time."[26]

Another area for improvement found in prior studies is reporting the search strategy to enhance reproducibility and transparency. Reproducibility of systematic review searches can be improved by reporting the names of the databases searched;[27] describing the procedures used for finding included studies;[28] reporting keyword searches;[29] and reporting date limiters.[30] Even after the availability of standards for reporting systematic reviews, many authors still failed to properly describe their methods.[31]

Criteria to Analyze the Systematic Review Searches

The Campbell Collaboration has the most developed set of guidelines for conducting systematic reviews on interventions in social sciences disciplines. However, no published studies have exclusively used the May 2017 version of the Campbell Collaboration's MECCIR standards to evaluate the search procedures of systematic reviews. Prior studies have based their evaluation criteria on the Campbell Collaboration's 2012 checklist;[32] the QUOROM (Quality of Reporting Meta-analyses) statement;[33] and a unique list of quality criteria based on Campbell, Cochrane, and What Works Clearinghouse.[34] Additional studies developed their own criteria for evaluating systematic review search methods.[35] We chose to use the MECCIR standards due to the Campbell Collaboration's established reputation and thorough standards that are aimed to minimize bias and increase reproducibility and transparency.

Methods

Study Eligibility Criteria

Our study analyzed systematic reviews and meta-analyses, published in academic journals, on K–12 mathematics education. A study was considered a systematic review if "systematic review" or "meta-analysis" appeared in the title or abstract; or if the study identified the databases searched, included a search strategy, and provided inclusion and exclusion criteria (see table 1). We defined mathematics education as educational interventions designed to improve student comprehension or learning of mathematics. Mathematics was more specifically defined to encompass subjects traditionally taught in kindergarten through twelfth grades, such as general mathematics, algebra, geometry, calculus, precalculus, and trigonometry. Reviews involving STEM or multiple subject areas were included as long as mathematics results were reported separately; and reviews investigating both K–12 and college students were included if the K–12 results were reported separately. Reviews that focused on teachers as the population group were excluded. In this study, educational interventions included instruction that occurs in a classroom setting, which can involve the use of technology, but students

TABLE 1
Inclusion and Exclusion Criteria

	Inclusion Criteria	Exclusion Criteria
Study Type	Systematic review or meta-analysis appears in the title or abstract; or study describes databases searched, includes search strategy, and provides inclusion/exclusion criteria	Study that is not a systematic review or meta-analysis
Subject	Mathematics (study can mention STEM or multiple subjects, but results on mathematics must be reported separately)	Multiple subjects or STEM (science, technology, engineering, mathematics) as a whole, where mathematics results were not reported separately
Population	Students in kindergarten through twelfth grade (if study includes both K–12 and college students, the study was included as long as K–12 results were reported separately)	Teachers, college or university students, or non-K–12 students
Educational Intervention	Face-to-face classroom instruction, teaching methods, instructional materials or technology, or curriculum	Non-classroom intervention tied to mathematics as one component of the study (such as the effectiveness of charter schools on STEM education), focus is not on mathematics or the instructional method
Publication Type	Academic journal articles	Content not published in academic journals
Language of Publication	English	Non-English
Publication Date	October 2014–April 2018	Prior to October 2014

and teachers must be present in the same physical location. Educational interventions may include: activities, instruction, interaction, teaching strategies, teaching methods, classroom techniques, computer-assisted instruction, software, instructional materials, instructional innovation, and curricular programs. Only English language articles were included. Since the Campbell Collaboration's MECCIR standards for conducting and reporting systematic reviews were initially adopted in October 2014, database searches were limited to journal articles published between October 2014 and April 2018.

Search

The following databases were searched: ERIC (EBSCO), Education Source (EBSCO), Academic Search Ultimate (EBSCO), and Compendex (Engineering Village) with final searches run on April 20, 2018. MathSciNet and Applied Science and Technology Source Ultimate were searched, but no relevant citations were found. The search strategies included two main concepts: mathematics and systematic reviews or meta-analyses (see table 2). Keywords and phrases representing the concepts were used to search the title and abstract fields of all databases. We used the database thesaurus or subject terms index to identify subject headings representing the concepts. These database-specific subject headings were used to search the subject or descriptor field for the appropriate database. The concept representing K–12 students was not included in the search so we could capture the topic more broadly. Instead, the grade level was used as one of the inclusion and exclusion criteria during the selection process.

TABLE 2
ERIC (EBSCO) Search Strategy

Concept	Field	Search Terms
Mathematics	Descriptor	DE "Mathematics" OR DE "Algebra" OR DE "Arithmetic" OR DE "Calculus" OR DE "Geometry" OR DE "Probability" OR DE "Statistics" OR DE "Trigonometry"
		OR
Mathematics	Title	TI (math* OR algebra OR geometry OR calculus OR precalculus OR pre-calculus OR trigonometry)
		OR
Mathematics	Abstract	AB (math* OR algebra OR geometry OR calculus OR precalculus OR pre-calculus OR trigonometry)
		AND
Systematic Review or Meta-Analysis	Descriptor	(DE "Meta Analysis" OR DE "Literature Reviews")
		OR
Systematic Review or Meta-Analysis	Title	TI ((literature or systematic) n2 review) or (meta n1 analysis) or (research n2 synthesis) or (evidence n2 synthesis))
		OR
Systematic Review or Meta-Analysis	Abstract	AB (((systematic or literature) n2 review) or (meta n1 analysis) or (research n2 synthesis) or (evidence n2 synthesis))

Selection Process

Search results from each of the databases were exported to RefWorks, a citation management software application, where duplicates were removed. Remaining references were imported into Rayyan, a web-based application designed for screening references used in systematic reviews.[36] The selection process involved two phases: title/abstract screening for exclusion and full-text screening for inclusion. Rayyan facilitated this process by allowing a screener to mark each reference as "include," "exclude," or "undecided."

During the exclusion phase, the title/abstract screening process was piloted to ensure interrater reliability by choosing a small set of references to be independently screened by each of the study authors. We used our exclusion criteria in determining references to mark for exclusion from our study based solely on reading the title and abstract for each reference. Exclusion disagreements were discussed and settled by consensus to better calibrate the title/abstract screening process. Then, the remaining references were independently screened for exclusion by authors, grouped into screening pairs, using Rayyan's blinding feature to veil screening decisions from each author. As in the pilot phase, disagreements in exclusion decisions were discussed by each screening pair to arrive at a consensus.

For the inclusion phase, the references marked in Rayyan as "include" or "undecided" during the title/abstract screening were divided among each screening pair to independently complete the full-text screening. We obtained a PDF and attached it to each reference for this phase of the process. We used our inclusion criteria to determine which articles to include in the study. Disagreements in screening decisions for inclusion were discussed by each screening pair to arrive at a consensus.

Coding and Appraisal Process

The coding form for appraising the reviews meeting the study eligibility criteria was created in Google Forms. We developed appraisal questions based on elements related to search methods and reports contained within three documents:

- Methodological Expectations of Campbell Collaboration Intervention Reviews (MECCIR)—Conduct Standards[37]
- Methodological Expectations of Campbell Collaboration Intervention Reviews (MECCIR)—Reporting Standards[38]
- PRESS Peer Review of Electronic Search Strategies: 2015 Guideline Explanation and Elaboration (PRESS E&E)[39]

We chose the Campbell Collaboration's MECCIR Conduct and Reporting Standards because they focus on systematic reviews for topics in the social sciences, including education. The numbered elements begin with an identifier consisting of C, for Conducting, or R, for reporting, indicating the set of standards to which the element belongs. The MECCIR Conduct Standards consists of 80 elements grouped into nine sections. We identified elements within the section "Planning the review methods at protocol stage" to develop the appraisal questions related to planning and conducting search strategies. These included: "Ensure that all relevant databases have been properly searched" (C24), "Searching for grey literature" (C28), "Searching within other reviews" (C29), "Searching reference lists" (C30), "Searching by contacting relevant individuals and organizations" (C31), and "Rerunning searches" (C37). Standard C24 was operationalized as searching ERIC and one other education database. PsycINFO counted as an education database if the review topic related to special education. There are 108 ele-

ments grouped into 15 sections of the MECCIR Reporting Standards. Similarly, we identified elements within five of the sections to develop questions on reporting of search strategies. The sections included: "Abstract" (R6), "Search methods for identification of studies" (R34–R36, R38–R39), "Results—Description of studies" (R55), and "Discussion" (R100).

We used PRESS to evaluate "structuring search strategies for bibliographic databases" (C32). Although the PRESS Checklist was originally developed to evaluate searches for the health sciences, it easily applies to the social sciences. Additionally, it is the only validated tool for evaluating search strategies for systematic reviews.[40] PRESS has a list of six elements: translation of the search, Boolean and proximity, subject headings, textword searching, spelling and syntax, and limits and filters. Evaluators are then asked to assess the search overall.

We piloted several iterations of the coding form. Originally, we designed the coding form questions to determine if MECCIR standards were "met," "partially met," or "not met" by the reviews included in our study. All authors independently coded the same review; then, as a group, we discussed ways to clarify the wording of questions to minimize potential coding disagreements, such as adding text illustrating conditions under which a standard was met or not met. Eventually, some answer options were changed to "met," "not met," or "unclear." We added comment boxes allowing us to capture potentially interesting patterns, similarities, and differences observed during our appraisal of reviews. Some data points included: names of databases searched; titles of journals searched; types and sources of grey literature searched; database limiters used; number of citations retrieved from database searches, number of duplicates, and final number of included studies; any systematic review standards mentioned; and any mention of the What Works Clearinghouse.

Also, we removed questions for a variety of reasons. Some involved conducting standard elements that we would not be able to determine as having been executed, such as: "Plan in advance the methods to be used for identifying studies." Questions relating to similar information found in both the conducting and reporting standards were eliminated or collapsed into one question. Some questions related to standards that do not apply to topics in education were removed. Finally, some questions related to standards with multiple parts were unbundled or separated into multiple questions to allow coding as "met" or "not met" for each of the parts. We coded questions related to the PRESS Checklist only if an exact search was provided in the review, using keywords and Boolean operators, and not simply a list of terms separated by commas. For each of the seven PRESS elements, the evaluator marked no revisions suggested, suggested revisions, or revisions required.

We tested each iteration of the coding form using a small sample of reviews. Once we finalized the questions, two authors independently coded each of the reviews. Coding conflicts were discussed by each coding pair to arrive at a consensus. After coding the searches with the PRESS checklist, we calibrated our evaluation of the PRESS elements as a group to differentiate between revisions required and revisions suggested.

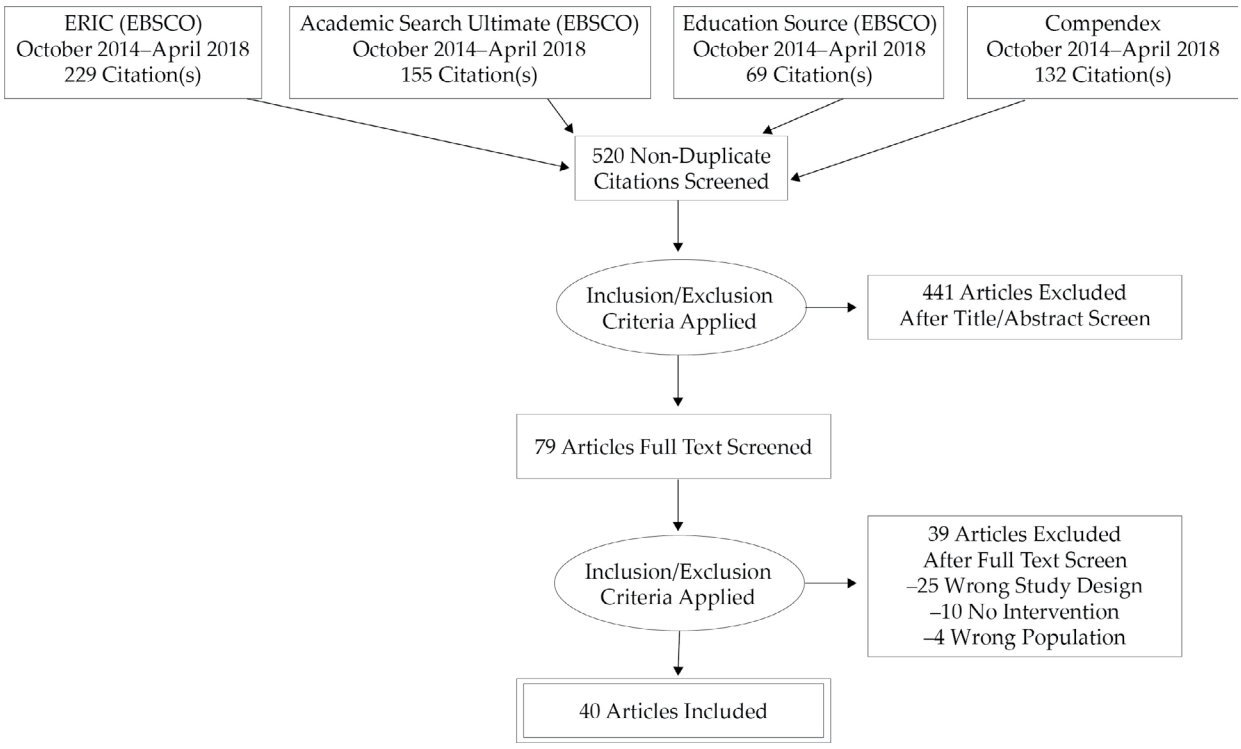
Results

Included Studies

After retrieving and screening citations, 40 systematic reviews were included. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Flowchart (see figure 1) shows the number of citations retrieved from each database and screened at each stage. Appendix A provides the list of citations of the included reviews. These reviews were published

in 32 journals, with two journals, *Journal of Learning Disabilities* and *Education Research Review*, publishing three reviews each. In reviewing the topics and populations of the reviews, half (21) focused on learning disabilities and/or math difficulties. Populations were balanced between primary and secondary students, with 13 reviews covering kindergarten through twelfth grades.

FIGURE 1
PRISMA Flowchart



Search Methods and Reporting

The coding form covered the strategies of database searching, grey literature searching, searching within references, searching individual journals, website searching, and contacting groups and/or authors. Table 3 provides the numbers of the studies meeting the standards within each search strategy type. In the reporting of the findings for each category on the coding form, the MECCIR standard number (such as C37, R6) is included when coded characteristics is from the standards.

TABLE 3
Summary of Coded Characteristics

Topic	Standard[1]	Action That Needed to Be Completed or Reported	# Which Met Standard	Total Sample[2]	%
Database Search	C24 (M)	Ensure that all relevant databases have been properly searched[3]	25	40	63%
	C37 (HD)	Search within 12 months of publication	1	5	20%

TABLE 3
Summary of Coded Characteristics

Topic	Standard[1]	Action That Needed to Be Completed or Reported	# Which Met Standard	Total Sample[2]	%
Database Search	R34 (M)	Complete list of databases provided	26	40	65%
		Database platforms provided	5	40	13%
		Dates covered by databases provided	26	40	65%
	R36 (M)	Search restrictions reported	38	40	95%
	R35 (M)	Last date searched reported	5	40	13%
	R38 (M)	Provided exact searches for databases	6	40	15%
	R6 (M)	Provided date of last search in abstract	2	40	5%
	R6 (M)	Provided list of databases searched in abstract	2	40	5%
Grey Literature Search	C28 (M)	Grey literature search conducted	10	40	25%
	R39 (HD)	Grey literature searches provided	2	10	20%
Reference Searching	C30 (M)	Searching within references conducted	21	40	53%
	C29 (M)	Searching within other reviews or systematic reviews conducted	9	40	23%
	R34 (M)	Searched reference lists	24	27	89%
Searching Individual Journals	*	Searched journals	22	40	55%
	*	Provided journal titles	20	22	91%
Contacting Authors	C31(HD)	Contacted authors/groups	1	40	3%
	R39 (HD)	Reported contact methods	1	1	100%
Searching Websites	R34 (M)	Searched websites	2	40	5%
	R39 (HD)	Reported search strategy for websites	0	2	0%
Search Results	R55 (M)	Number of references included identified and included list provided	30	40	75%
		Flowchart	8	40	20%
Acknowledgments	R100 (M)	Did authors acknowledge potential limitations of the search?	18	40	45%
	*	Did authors acknowledge a librarian?	0	40	0%

[1]Notation for standards: M: Mandatory; HD: Highly desirable; *: not part of the standards.
[2]The total sample size changed based on the number of studies that reported a given criterion.
[3]Searched ERIC and one other education database.

Database Searching

Out of all the possible search options, database searches are mentioned most often in MECCIR and require the most information to be reported. Table 3 provides more details about the search standards. Standard R34 requires that reviews report the names, platforms, and dates covered by the databases. Fourteen reviews did not list all of the databases searched, with one providing none. ERIC was the most frequently reported database searched, with 30 (77%) reviews, and PsycINFO was second with 25 (64%). The most frequently searched databases are shown in table 4. Several reviews listed just the vendor as the resource (such as EBSCO or ProQuest) instead of providing database names. PsycINFO was sometimes misspelled by adding an "h" (like Psychinfo). The platforms of the databases searched were only provided in 5 out of 39 reviews. After analyzing the topics of the reviews, we determined that only 25 searched at least ERIC and one other education database (C24), with 15 reviews lacking a comprehensive search. The databases searched should also be provided in the abstract (R6), but only 5 percent (2) of the studies met this standard.

The last date searched by the review (R35) was only provided by five reviews, and dates should be within 12 months of publication (C37), which only one of the five met. The date should also be provided in the abstract (R6); only two studies met this standard.

TABLE 4
Top 8 Databases Searched

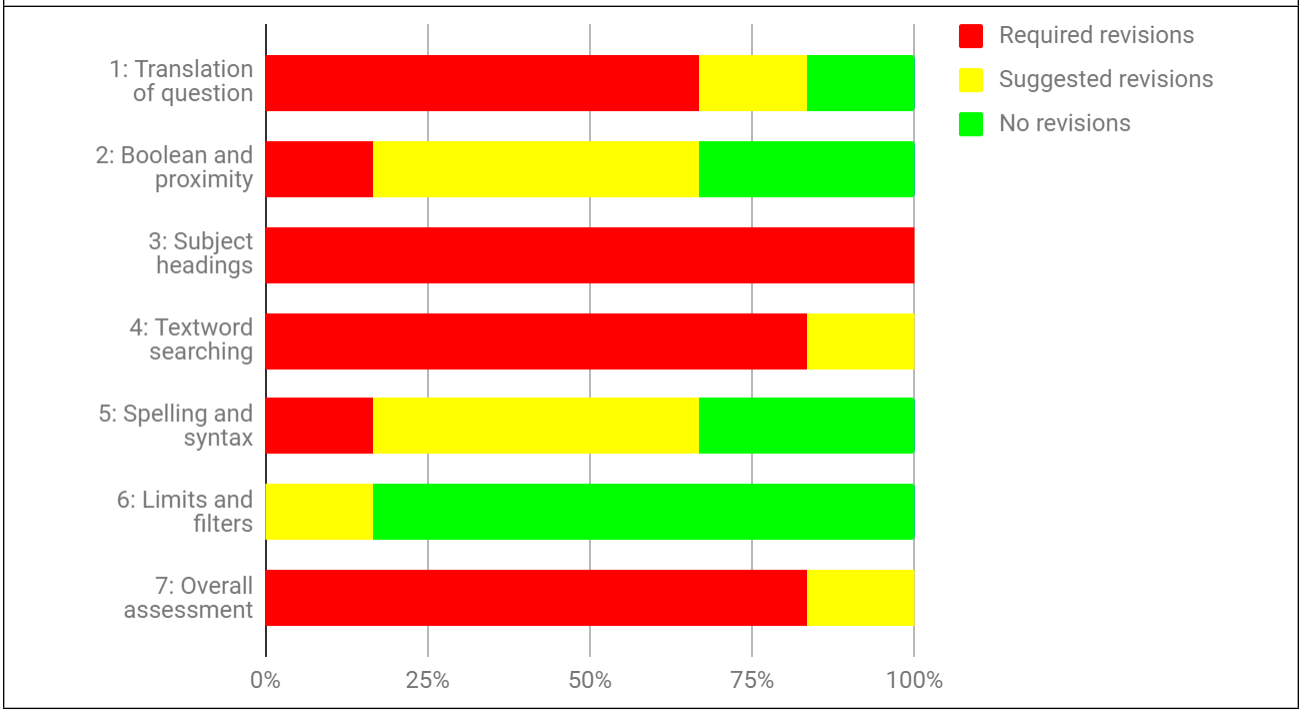
Rank	Resource	n	Percent
1	ERIC	30	77%
2	PsycINFO	25	64%
3	Academic Search Complete	13	33%
4	Google Scholar	12	31%
5	EBSCO Databases	9	23%
6	ProQuest	8	21%
7	JSTOR	7	18%
8	Science Direct	5	13%

Note: Only 39 reviews reported databases. The percentages reported are out of 39.

PRESS Checklist of Reported Search

Only six reviews (15%) provided a search that could be evaluated using the PRESS checklist.[41] To meet standard R38, reviews needed to provide exact search strings. Figure 2 provides the overall ratings that the reviews received on each of the PRESS elements. All of the reviews' searches were labeled as requiring some revision. Only one review needed one element to be revised, and most needed four to five elements revised. All of the reviews had issues with the element of subject headings. When considering the keyword element, several of the reviews did not fully consider multiple endings of words. In addition, some reviews mixed outcome terms with intervention terms in the search. For example, one review searched for the intervention terms of problem solving, computation, and algebra, with the outcome terms of math academic achievement and math performance. The search was structured as "problem solving" OR "computation" OR "algebra" OR "math academic achievement" OR "math performance."[42] Another review searched for a phrase that is not commonly used, "effective math learning opportunities."[43] This was the only term used for this concept.

FIGURE 2
PRESS Checklist Evaluation



Journals Searched

Although not part of the MECCIR standards, 22 (55%) reviews stated that they searched journals, with 20 out of 22 providing the journal titles. The top five journals are provided in table 5, all of which focus on special education issues or special populations. More than half of the reviews searched *Exceptional Children*, *Journal of Special Education*, and *Remedial and Special Education*.

Grey Literature

Ten of the reviews (25%) reported searching grey literature (unpublished sources) (C28), with most (8 of 10) searching for dissertations/theses. Two reviews searched for conference papers, and two sought white papers. However, only two of the reviews reported the grey literature search strategies or specific resources searched (R39).

Other Search Strategies

Twenty-one reviews mentioned searching within included references (C30), and nine searched within other related reviews (C29). Of those that reported searching in references, most (79%) reported details of these searches (R34). Only one review reported contacting authors/groups (C31) and also provided a description of the contact (R39).

TABLE 5
Top Journals Handsearched in Reviews

Rank	Resource	n	Percent
1	*Exceptional Children*	14	70%
2	*Journal of Special Education*	13	65%
3	*Remedial and Special Education*	11	55%
4	*Journal of Learning Disabilities*	10	50%
4	*Learning Disabilities Quarterly*	10	50%
5	*Learning Disabilities Research & Practice*	6	30%

Note: Only 20 reviews reported handsearching journals.
The percentages reported are out of 20.

Two reviews reported searching websites (R34), but neither of these reviews reported their strategies (R39).

Limits of Search

Most of the reviews (95%) reported limits or restrictions to the search (R36), even if they did not report the search. In recording limits of the search, four categories were coded: peer review, publication format, language, and date (see table 6). Any others listed were also collected. Nine of the reviews were limited to all four of these restrictions, while nine only reported one restriction. Most of the reviews stated that they were limiting to peer review or limiting by publication format. One review went so far as to limit to only those studies available through open access.

TABLE 6

Use of Limiters

	Description	# of Reviews	Percent
Specific Types of Limiters	Peer Review	27	71%
	Publication Format	26	68%
	Language	19	50%
	Date	26	68%
Number of Limits Used	All	9	24%
	3 out of 4	13	34%
	2 out of 4	7	18%
	1 out of 4	9	24%

Only 38 reviews reported using limiters. The percentages reported are out of 38.

Reporting of Search Results

While all 40 reviews provided the number of included studies (R55), two did not provide the number explicitly. Only eight reviews included a flowchart (R55), similar to our figure 1. The average number of included articles was 25, ranging from seven to 75. The number of retrieved articles averaged 1,469 citations, and ranged from 15 to 9,450.

Other Characteristics

None of the reviews acknowledged a librarian as assisting with the search. Very few listed a standard within the review report such as PRISMA. Nearly half mentioned the potential limitations of their review related to the search (R100).

Discussion

Overall, the included reviews lacked transparency and comprehensiveness of the search. The procedures used to search for studies were reported in detail in only a few of the included reviews. While the lack of search strategy reporting was also found in prior evaluations of systematic reviews,[44] our findings highlight the issues specific to this set of reviews related to K–12 mathematics education and the implications for librarians and researchers conducting reviews in education. Transparent search reporting would follow the MECCIR standards by providing the names of databases and other resources searched, the exact search strategy for each database, the limiters used (such as date, publication type, language), and the date the search was conducted. Only if the exact search strategy is reported can the reader adequately evaluate a search's quality. If the search is reported comprehensively, then the reader can evaluate if the appropriate sources were searched, the appropriate search terms were used

for the research question, Boolean and proximity operators were used appropriately, both text and subject headings were searched, and limits and filters were applicable and used correctly.[45] The date of the last search is important for evaluating the coverage of the search and the currency of the review.

The lack of search method reporting also inhibits the ability of readers to replicate the search. Reproducibility is an important component of all research reporting. Discussion of reproducibility is taking place within mathematics education as well as LIS. A recent editorial in *Journal for Research in Mathematics Education* discussed the role of replication in mathematics education research.[46] Cai, Morris, Hohensee, Hwang, Robison, and Hiebert encouraged authors to "document their work in sufficient detail so as to make conceptual replications possible."[47] Sayre and Riegelman described how librarians can support reproducibility through collaborating with researchers using systematic review methods.[48] By describing the search procedures used to generate the studies for the synthesis, researchers can ensure that others can build on their work and appropriately evaluate the procedures used to find the included studies.

Database Searching

MECCIR Conduct and Reporting Standards refer researchers to *Searching for Studies: A Guide to Information Retrieval for Campbell Systematic Reviews* for detailed guidance on selecting relevant databases. The *Searching for Studies* guide lists ERIC as the major subject database for education literature.[49] ERIC was the most reported database, among the 40 studies we appraised, yet roughly 20 percent did not report searching ERIC at all. Additionally, we found that 37 percent of the reviews failed to search major databases relevant to the topic. For example, reviews did not report searching PsycINFO for topics involving learning disabilities or special education. There is no prescribed minimum number of databases to search, although a single database is not sufficient.[50] Adding multidisciplinary databases or those covering subject areas related to the topic ensures broad enough coverage in locating relevant studies while minimizing selection bias.

When evaluating the appropriateness of databases searched in a review, it is important to consider access. A major factor in database selection is the availability of subscription-based resources at the researcher's institution. Most institutions subscribe to ERIC through a vendor platform such as EBSCO or ProQuest and access is freely available through the US Department of Education. Despite the free access to ERIC, not all reviews reported searching this resource. Researchers are advised to consult with an information specialist or librarian to ensure all the appropriate resources are searched and to avoid duplication of effort by searching unnecessary resources.[51]

MECCIR standards require researchers to report all databases used in the literature search, including database name and platform or provider. Our appraisal found that 35 percent of the reviews failed to report a complete list of the databases searched, making it impossible to accurately replicate the search. Only 13 percent of the reviews provided the platform for the database searched. The exact search executed using ERIC on the EBSCO platform may yield different results than ERIC on the ProQuest platform due to differences in platform search algorithms. Accurately assessing the appropriateness of the database to the topic and testing or replicating the search strategy requires both the database name and platform.

When databases were reported, approximately 20 percent of the reviews failed to provide specific database names and instead listed the platforms alone such as "Ebsco databases"

or "Proquest." Providing the platform alone makes it impossible to determine the specific database or selection of databases searched. To emphasize the importance of this issue, most institutions subscribe to a subset of more than 190 bibliographic databases and primary source collections offered on the EBSCO platform. A similar problem arises with the nearly 20 percent of reviews that reported searching JSTOR. JSTOR offers full-text access to journals grouped into nine collections, with education being one of the 19 subcollections within the social sciences category. Each institution may purchase access to any number and variety of subcollections for its users, making it impossible to determine which collection the researcher actually searched. These issues involving database names and platforms lead us to question whether some researchers actually understand the scope and coverage of the resources they are searching.

Subject heading searches are crucial to the search quality, yet none of the included reviews used subject headings. The use of both natural language (like keywords) and subject headings for searches is not only recommended based on empirical evidence[52] but also is included in Campbell's *Searching for Studies*.[53] Controlled vocabulary is designed to retrieve "articles that may use different terms to describe the same concept."[54] The available subject terms may not correspond to the terminologies used by the researchers in their search; therefore, both keywords and controlled vocabulary are recommended for a search strategy.[55] In a study comparing keyword and subject searches for a particular topic in medicine, Jenuwine and Floyd found that subject searching yielded higher specificity but lower sensitivity in the retrieval of relevant studies.[56] To have a comprehensive search, all appropriate fields should be searched for synonyms of that concept.

Other Types of Searching

"The goal of most systematic search strategies is to identify all empirical work meeting explicit eligibility criteria."[57] Our findings indicate that the researchers ignored certain types of empirical works. Only 25 percent of the included reviews searched grey literature. Searching for grey literature is important because, without the results reported in grey literature, the findings of a synthesis can be skewed.[58] Researchers were more likely to conduct reference list checking. Half of the reviews checked the reference lists of related reviews and conducted handsearches to find potential studies. Using these nondatabase search strategies can be useful in many ways. When commenting on the necessity of handsearching, the *Searching for Studies* guide gave two reasons: (1) indexing of electronic databases is not perfect, and (2) even included in a database, some studies may not have the right terms in the titles or abstracts fields to make them easily identifiable.[59] As for reference list checking, a Cochrane methodology review revealed that "relevant studies identified through checking reference lists ranged from 2.5% to 42.7%."[60] Horsley, Dingwall, and Sampson demonstrated that a good portion of relevant studies could have been missed without reference list checking.[61]

Limiting to Peer-Reviewed Journals

The majority of reviews included in our analysis limited their results to peer-reviewed journal articles, which could potentially bias the findings of the systematic review or meta-analysis. Publication bias is when, due to the nature of the findings, an author self-selects not to publish or the article is rejected from a journal.[62] The systematic review method is designed to

eliminate as much bias as possible by using comprehensive search procedures.[63] Therefore, it is important to minimize bias by doing comprehensive reviews gathered from grey literature, conference proceedings, or other nonjournal sources.

Acknowledgment of Librarians

Finally, none of the reviews acknowledged a librarian, which most likely means that a librarian was not involved in the systematic review search process. When a librarian collaborates on a systematic review, the quality of the overall review, especially the search, is improved.[64] Throughout the evaluation of these reviews, it was clear that the searches were not fully reported and that the searches that were reported were not comprehensive and did not meet the standards. Systematic reviews are well suited for collaborations between librarians and researchers—researchers know what they are looking for and librarians know how to search.

Implications

Based on the findings of our study, there are several implications for social sciences librarians to consider regarding systematic reviews. First, librarians can advocate for use of the MECCIR standards by increasing awareness and improving access. The Campbell Collaboration website has navigational issues, and the standards are updated frequently. Librarians can link to the standards on LibGuides or other library webpages, mention them in library instruction sessions, reach out to instructors of research methods courses, and discuss the standards during research consultations. In addition, librarians can guide researchers in applying the standards, especially those focused on search processes. The search process standards have not been fully adapted to the social sciences and include many examples and references to medical resources.

Second, social sciences librarians should be aware that researchers may not seek collaboration when working on systematic reviews. Librarians must be proactive in promoting their potential roles in the systematic review collaboration—posting services on library webpages, discussing the services with new faculty during orientations, and describing services during meetings with graduate students and faculty. The primary collaborative role would involve designing and conducting searches. Other potential collaboration activities include searching for funding, applying for grants, and an authorship role based on writing the search methods.

Finally, social sciences librarians can draw upon a broad knowledge base during collaborations to improve the quality of reviews. Many librarians already possess the searching skills and expertise that can be directly applied to search strategy development in systematic reviews. As the standards call for comprehensive searches, there are several steps that librarians can take to improve search strategies. Using their knowledge of search syntax, librarians can work with researchers to develop searches based on effective use of truncation, phrase searching, and proximity operators. For example, librarians could identify instances where using truncation or proximity operators would yield more accurate search results than simply using search terms and Boolean operators. Librarians can collaborate with researchers to identify synonyms and prevent them from grouping search terms together that should actually be separate concepts. Based on the researcher's topic, the librarian can demonstrate how to use thesauri or database subject indexes to find relevant subject terms and ensure that concepts are appropriately represented. Some researchers may want to handsearch a select number of journals relevant to their topic when databases already index many of the same journals. Librarians can advise researchers on database journal coverage to avoid duplication of their effort.

Librarians have unique knowledge about resources, such as databases, journals, and vendor platforms. Librarians know the scope and coverage of the databases in their disciplines and their institutional access to those databases. Additionally, sometimes sections of journals are not indexed, such as supplements or conference abstracts, which would require searching other resources in addition to databases. Librarians are aware of database indexing of preprints. For example, preprints are indexed in PsycINFO, Scopus, and Academic Search Ultimate, but not ERIC. Librarians can help researchers understand the potential for bias when limiting searching to only bibliographic databases. Librarians know where to find conference proceedings, dissertations, white papers, and other types of grey literature relevant to their field, as comprehensiveness aids in reducing bias. Librarians are well versed in the pitfalls of limiting searches to peer-review journals and should make researchers aware of how limiting to specific publication types can bias their search results.

Accurately describing the search process provides transparency and aids in replication of the search. Librarians are able to provide guidance on describing the search strategy, such as reporting the names of the databases as well as the vendor platforms. Advocating to provide the exact search strategy allows readers to evaluate the quality of the review and replicate the search. When documenting the date range used in a search, librarians should advise researchers to provide a justification. Finally, librarians can remind researchers of the need to document and report any search restrictions as well as the date of the last search.

Limitations and Future Research

Our research has two primary limitations. First, we did not search for studies in all of the places recommended for comprehensive systematic review searching. We only searched for studies in academic journals indexed in four databases and did not consider reference searching, looking at prior literature reviews, individual journal searching, or contacting individuals. Our decision to not pursue these avenues was due to our goal of retrieving a sample of systematic reviews rather than comprehensively searching for every systematic review on the topic. Second, our analysis only assessed systematic reviews on the topic of mathematics interventions in K–12 settings and within these the majority focus on interventions for students with learning disabilities. Therefore, our findings might not be generalizable to all education systematic reviews. Future research should investigate the reporting of search methods in other education areas and social sciences disciplines. Additionally, social sciences librarians should analyze the impact of librarian collaboration on search strategies for social sciences systematic reviews to reinforce the case for librarian collaboration.

Conclusion

This study contributes to the LIS literature on systematic reviews by applying the MECCIR standards to analyze the search quality of education reviews and considering the implications for social sciences librarians. Based on our analysis of 40 published systematic reviews in mathematics education, researchers are not meeting most of the MECCIR standards when conducting and reporting the search strategies. As systematic reviews are continuing to grow in popularity, social sciences researchers may be conducting systematic reviews and meta-analyses without knowing that collaboration with a librarian would greatly improve the search process leading to improvement of the quality of the review.

Even if librarians are unfamiliar with systematic reviews, based on the reported search strategies in the included reviews, librarians could have played an important role in improving the accuracy of the searches. Librarians know the information resources essential to their disciplines and know how to develop searches using relevant keywords, the appropriate syntax, proximity operators, truncation, and subject headings within these resources. Social sciences librarians are equipped with the knowledge and skills necessary to collaborate with social sciences researchers in developing systematic review searches and should be confident in their ability to design and execute a comprehensive search. By learning more about systematic reviews methods and standards, librarians are poised to be expert collaborators, resulting in higher quality reviews for the researcher, the librarian, and the institutions they serve.

Appendix A. Included Reviews

Bano, Muneera, Didar Zowghi, Matthew Kearney, Sandra Schuck, and Peter Aubusson. "Mobile Learning for Science and Mathematics School Education: A Systematic Review of Empirical Evidence." *Computers & Education* 121, (2018): 30-58. https://doi.org/10.1016/j.compedu.2018.02.006.

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