10-2020

An Early Look at a Scoping Review of Systematic Review Methodologies in Engineering

Jason Reed
Purdue University, reed252@purdue.edu

Margaret Phillips
Purdue University, phill201@purdue.edu

Amy Van Epps
Harvard University, amy_vanepps@harvard.edu

Dave Zwicky
Purdue University

An Early Look at a Scoping Review of Systematic Review Methodologies in Engineering

Jason Reed
Libraries & School of Information Studies
Purdue University
West Lafayette, IN USA
reed252@purdue.edu

Margaret Phillips
Libraries & School of Information Studies
Purdue University
West Lafayette, IN USA
phill201@purdue.edu

Amy S. Van Epps
Harvard Library
Harvard University
Cambridge, MA USA
amy_vanepps@harvard.edu

Dave Zwicky
Libraries & School of Information Studies
Purdue University
West Lafayette, IN USA
dzwicky@purdue.edu

***Abstract*—This research work-in-progress paper is a scoping review of published systematic literature reviews (SLRs) in engineering. SLRs are considered one of the highest levels of proof for evidence based decision making, but they are only as good as the methods used, starting with the search strategy. With studies described as "systematic literature reviews" proliferating through engineering disciplines, including engineering education, it is necessary to examine how well these studies reflect a methodologically sound understanding of established SLR processes. The initial search returned 4,992 results, after removing duplicates. After completing the abstract review, we included 2,674 results for full text review. A preliminary analysis of the citations included for full text shows that SLRs have increased dramatically over the past decade in engineering education and approximately 14.1% of included results for full text analysis contain an education related term in the title, abstract, or publication title. This trend implies that more education on the SLR research method may be needed in engineering education graduate programs and through professional development opportunities.**

***Index Terms*—Systematic literature reviews, engineering, engineering education**

I. Introduction

The origins of the SLR research method are presented differently depending on what articles are read. Among the differences there is consensus of the method dating to the 18th century; the most frequently cited first use of this method is within the medical sciences, a 1757 study by Dr. James Lind on the treatment of scurvy[1] [1], [2]. The medical sciences are where the need to collect and codify the results of multiple studies is necessary for regular presentation of the state of knowledge on a topic or disease [1], [3]. The use of SLRs has been growing in medicine from sporadic use before the 80s, to more than 10,000 published each year [4]. In parallel with the growth of the SLR method in medicine, the method more generally developed further in the 70s and 80s, what Hong and Pluye [2] call the foundation period. This time period includes the introduction of the term 'meta-analysis' for the quantitative analysis, combining the results of multiple studies by Gene Glass in 1975[2], the emergence of quantitative case study in political science by Yin and Heald in 1975[3], and the development of online databases for easier bibliographic searching. During the 90s, the process of SLRs became codified, which can be seen in the establishment of the Cochrane Collaboration[4] in 1993 for medical sciences SLRs, the development of the EPPI-Centre[5] in 1995 for public policy research reviews, and the Campbell Collaboration[6], focusing on social and behavioral sciences reviews, in 2000. Some cross-field adoption began in the 1990s, as evidenced by the development of centers for coordinating and publishing reviews. From 2001 to the present, a time called diversification by Hong and Pluye [2], the SLR method has expanded further including the methodological documents for SLRs in the social sciences [5], software engineering SLRs [6], and the discovery and implementation in engineering education, generally marked by the 2014 Journal of Engineering Education article by Borrego, Foster, and Froyd [7] and quickly followed by the 2015 special session on the same topic at FIE [8].

One of the authors worked as the liaison to engineering education and has direct experience with the growth of SLRs within the discipline. Shortly after the process was introduced to librarians outside of the health sciences, an engineering education class requested a session on conducting SLRs, which led to the adoption of a modified SLR method in the graduate program required inquiry class. The requests prompted the development of an SLR primer [9] that was presented to the graduate students in the program to continue to develop knowledge and skills beyond the introduction in class.

SLRs are considered one of the highest levels of proof for evidence based decision making [10], but they are only as good as the methods used, starting with the search strategy. With studies described as "systematic reviews" proliferating through

[1] J. Lind, *A treatise on the scurvy. In three parts. Containing an inquiry into the nature, causes and cure of that disease. Together with a critical and chronological view of what has been published on the subject.* London: A. Millar in the Strand, 1757.

[2] G. V. Glass, "Primary, secondary, and meta-analysis of research," *Educational Researcher*, vol. 5, no. 10, pp. 3–8, Nov. 1976. DOI: 10.3102/0013189X005010003.

[3] R. Yin and K. Heald, "Using the case survey method to analyze policy studies," *Administrative Science Quarterly*, vol. 20, no. 3, pp. 371–381,

[4] https://cochrane.org

[5] https://eppi.ioe.ac.uk

[6] https://campbellcollaboration.org/

engineering disciplines, including engineering education, it is necessary to examine how well these studies reflect a methodologically sound understanding of established SLR processes.

The work is leading to a response to the following research questions: 1. To what extent is the systematic literature review (SLR) research method being applied in engineering disciplines? 2. How closely are systematic literature reviews (SLRS) that are published in engineering disciplines following established guidelines for the methodology?

II. Methods

This study is following a priori protocol, based on the PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation [11], which was uploaded and registered with the Open Science Framework [12]. The inclusion criteria for this study are: 1. journal articles of conference papers, 2. full text must be in English, 3. the study type must be a SLR and/or a meta-analysis that includes a SLR search, or intended to be one of these methodologies by the authors, 4. it must include a focus on engineering, excluding computer science and software engineering. Conference papers were included for this project to reflect the practice in engineering scholarship of presenting full length, peer reviewed papers at conferences. We will not include other article types because this project is focusing on published SLRs and meta-analyses. For the purposes of our study, a focus on engineering is defined as including an engineering author, publication in an engineering-related journal or conference, and/or use of engineering expertise in other areas, such as medicine. Software engineering and computer science were excluded because they are outside the scope of this study and they have a history of using the SLR method and have disciplinary guidelines for SLRs [6].

The systematic search strategy was built by an engineering liaison librarian with experience working on review projects [Phillips] and reviewed by two additional information experts with expertise in review projects [Reed] and engineering [Van Epps]. The search was conducted in the databases Compendex (Engineering Village, 1884-present) and INSPEC (Engineering Village, 1896-present). The search combines natural language terms for systematic reviews and engineering disciplines using Boolean terms to combine concepts as appropriate. The engineering disciplines terms are based on the National Academy of Engineering subject list [13]. The initial search was conducted July 25, 2019 and can be seen in its entirety in Fig. 1.

After the search was completed, we employed an overly inclusive method for the abstract review. Meaning, studies were only excluded at this stage if we determined the abstract clearly did not meet the inclusion criteria, if there was any uncertainty with a result, the study was included for full text screening. The abstract review was conducted using Rayyan, an open source software developed specifically to assist researchers conducting SLRs [14].

((”systematic review” or ”systematic literature review” or ”meta-analysis” or ”meta analysis”) WN KY) AND ((“aerospace engineering” OR “aeronautical engineering” OR “astronautical engineering” OR “bio* engineering” or ”biomedical engineering” OR “chemical engineering” OR “civil engineering” OR “construction engineering” or “environmental engineering” or ”structural engineering” or “electronic engineering” OR “electrical engineering” OR “computer engineering” OR “energy engineering” OR “nuclear engineering” OR “industrial engineering” or “manufacturing engineering” or “systems engineering” OR “operations research” OR “materials engineering” OR “mechanical engineering” OR “engineering education”) WN ALL)

Fig. 1. Search strategy for INSPEC

Prior to beginning the full abstract review, we conducted a pilot test of the inclusion/exclusion process. Taking advantage of the blinding option in Rayyan, each of us reviewed the same set of 100 abstracts and logged our include or exclude decision in Rayyan. We achieved an agreement percentage of 88.7% and a Fleiss kappa inter-rater reliability percentage of 43.7% (moderate agreement).We then met to discuss the discrepancies and formed a consensus on whether to include or exclude those abstracts. The remaining abstracts were reviewed by a single reviewer, with each of us responsible for a third of the remaining set.

A fourth reviewer [Zwicky], with experience working on engineering reviews, has been added to the team to assist with full text review. The same process will be followed for full text review, including the use of Rayyan and pilot testing to evaluate inter-rater reliability.

Once the full text review has been completed, the authors will begin the process of extracting data from each included full text. This study will use a custom data extraction sheet that has incorporated components from existing tools, AMSTAR (A MeaSurement Tool to Assess systematic Reviews) [15] and DART (Documentation And Appraisal Review Tool) [16] used to assess SLR quality, in addition to components from the PRISMA ScR Guidelines [11]. The data extraction sheet includes columns related to signifying the study is a SLR or meta-analysis, the use of a registered protocol, information on the search strategy, including databases searched, mention of including a librarian as co-author or consulting with a librarian, among other variables. We decided to create a custom form because this study is concerned with investigating how researchers developed their data set (how did they search for studies to review for inclusion) and how they reported their study. Existing tools include components measuring assessment of bias and evaluation of included study quality, both of which are important but are not relevant to this study's research questions. In addition to reporting overall findings

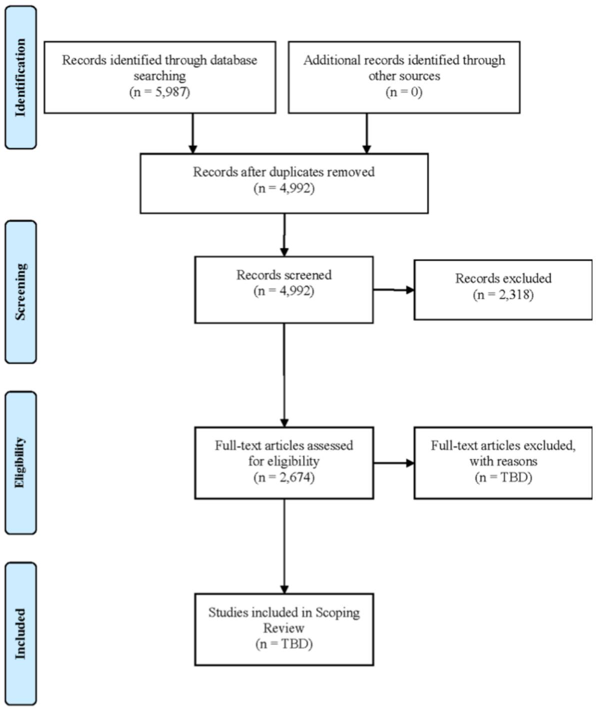

Fig. 2. Work-in-progress PRISM flow diagram for this scoping review

from all studies, the authors also plan to report findings broken down by engineering discipline subgroup (e.g., engineering education), as well as bibliometric analysis including journals published in and the most prolific authors/institutions.

III. Initial Results

A work-in-progress PRISMA flow diagram (Fig. 2) details the flow of information through the phases of this scoping review. The initial search of the databases Compendex and Inspec resulted in 5,987 records. After removing duplicates, 4,992 records remained for the first level of screening, the abstract review. We excluded 2,318 records for not meeting the inclusion criteria during the abstract level review, leaving 2,674 records for the next phase, the full text review. We are in the process of completing the remaining phases, assessing the full text articles for eligibility and determining the final number of studies in the scoping review. A preliminary scan of the citations in the full text set includes examples from nearly all sub-disciplines of engineering, including engineering education.

To get an initial understanding of the prominence the engineering education related papers in the full set and some of the papers' characteristics, we searched the the titles, abstracts, and publication titles of the 2,674 records in the full text set for the terms learn*, teach*, educat*, or curricul* (the use of the * symbol enables different forms of a word to be searched for simultaneously). Three-hundred seventy six (376) (or 14.1%) of the 2,674 papers have at least one of these terms in either the title, abstract or publication title fields. For the purposes of this work-in-progress paper, we refer to this set of 376 results as the "education-related" papers.

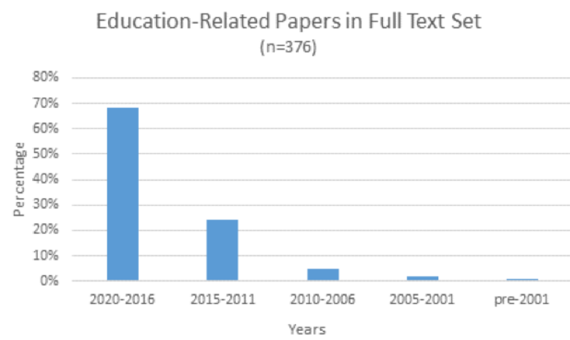

Fig. 3. Publication years of the "education-related" papers

TABLE I
Publication venues of "education related" papers

Publication Venue	# of Papers
ASEE Conference Proceedings	29
IEEE FIE Conference Proceedings	19
Computers and Education	13
ACM International Conference Proceeding Series	11
Journal of Engineering Education	10
Journal of Cleaner Production	8
Communications in Computer and Information Science	6
IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)	6
International Journal of Engineering Education	5
Advances in Intelligent Systems and Computing	5
Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)	4
International Journal of Emerging Technologies in Learning	4
IEEE Transactions on Learning Technologies	4
Computers in Human Behavior	3
European Journal of Engineering Education	3
Other publications (frequency ¡=2)	246
Total	376

The publication years of the papers in the "education-related" set range from 1992-2020. Fig 3. shows a publication year analysis of this set. Sixty-eight percent (68%) of the "education-related" papers were published between 2016-2020, and 24% between 2011-2015. Only 8% of the papers were published in 2010 or earlier.

Additionally, we analyzed the education-related paper set for publication venues (see Table I). Overall, the most common venues for publishing are the American Society of Engineering Education (ASEE) and IEEE Frontiers in Education (FIE) conference proceedings. Journal-wise, the most common publication venues are Computers and Education and Journal of Engineering Education.

A. Limitations

It should be noted that this is a preliminary analysis and some of the papers in the "education-set" may not truly be education-related. For example, the phrase "deep learning," was found in the title of at least one of the results, but without further assessment, it is not clear if this paper is truly education-related.

IV. Discussion

The next phase of this project will involve completing the scoping review. Given that we have narrowed our set of articles down to 2,674, the next step will be assessing the full text of those articles and excluding those that do not match our stated criteria. We will then extract data from the remaining studies and use it to determine the extent to which engineering disciplines are applying SLR methodology and how closely those published studies hew to established guidelines for said methodologies.

While we have more work to do before we can provide definitive answers to our research questions, analysis of our initial sample indicates several suggestive trends. Engineering education appears highly represented in the sample, even with the aforementioned limitations, with 14.1% of papers showing some education-related content. We can also see from this subset of the sample that engineering education as a field appears to have embraced the SLR methodology, with rapid and accelerating growth over the last ten years. This trend implies that more education on the SLR research method may be needed in engineering education graduate programs and through professional development opportunities. This would better prepare engineering education researchers to conduct systematic reviews and serve as peer reviewers for SLR conference and journal papers. Additionally, librarians at institutions with engineering education programs should reach out to graduate students and faculty members with offers to advise and/or partner on SLR projects. With the global disruptions caused by the COVID-19 crisis in 2020 and many engineering education faculty members and graduate students encountering challenges to their research plans, SLRs are one method that can be conducted entirely from a distance.

References

[1] M. Clarke, “Partially systematic thoughts on the history of systematic reviews,” *Systematic Reviews*, vol. 7, no. 1, Dec. 2018. DOI: 10.1186/s13643-018-0833-3.

[2] Q. N. Hong and P. Pluye, “Systematic reviews: A brief historical overview,” *Education for Information*, vol. 34, no. 4, pp. 261–276, Dec. 18, 2018. DOI: 10.3233/EFI-180219.

[3] T. Poklepović Peričić and S. Tanveer. (2019). Why systematic reviews matter, [Online]. Available: https://www.elsevier.com/connect/authors-update/why-systematic-reviews-matter (visited on 04/06/2020).

[4] M. Clarke and I. Chalmers, “Reflections on the history of systematic reviews,” *BMJ Evidence-Based Medicine*, vol. 23, no. 4, pp. 121–122, Aug. 2018. DOI: 10.1136/bmjebm-2018-110968.

[5] M. Petticrew and H. Roberts, *Systematic Reviews in the Social Sciences: A Practical Guide*. Wiley, ISBN: 978-1-4051-2110-1. (visited on 05/09/2018).

[6] B. A. Kitchenham and S. Charters, “Guidelines for performing systematic literature reviews in software engineering technical report,” EBSE-2007-01, 2007.

[7] M. Borrego, M. J. Foster, and J. E. Froyd, “Systematic literature reviews in engineering education and other developing interdisciplinary fields,” *Journal of Engineering Education*, vol. 103, no. 1, pp. 45–76, Jan. 1, 2014. DOI: 10.1002/jee.20038.

[8] J. E. Froyd, M. J. Foster, J. P. Martin, M. Borrego, H. S. Choe, and X. Chen, “Special session: Introduction to systematic reviews in engineering education research,” in *2015 IEEE Frontiers in Education Conference (FIE)*, Camino Real El Paso, El Paso, TX, USA: IEEE, Oct. 2015, pp. 1–3. DOI: 10.1109/FIE.2015.7344090.

[9] A. Van Epps and M. Phillips, *Systematic literature reviews: A primer*, 2016. [Online]. Available: https://docs.lib.purdue.edu/lib_fscm/29/.

[10] Oxford Centre for Evidence-based Medicine. (2009). Levels of evidence, [Online]. Available: https://www.cebm.net/2009/06/oxford-centre-evidence-based-medicine-levels-evidence-march-2009/ (visited on 04/06/2020).

[11] A. C. Tricco, E. Lillie, W. Zarin, K. K. O’Brien, H. Colquhoun, D. Levac, D. Moher, M. D. Peters, T. Horsley, L. Weeks, S. Hempel, E. A. Akl, C. Chang, J. McGowan, L. Stewart, L. Hartling, A. Aldcroft, M. G. Wilson, C. Garritty, S. Lewin, C. M. Godfrey, M. T. Macdonald, E. V. Langlois, K. Soares-Weiser, J. Moriarty, T. Clifford, Ö. Tunçalp, and S. E. Straus, “PRISMA extension for scoping reviews (PRISMA-ScR): Checklist and explanation,” *Annals of Internal Medicine*, vol. 169, no. 7, p. 467, Oct. 2, 2018. DOI: 10.7326/M18-0850.

[12] A. S. Van Epps, J. B. Reed, M. Phillips, and D. Zwicky. (Jul. 25, 2019). Use of systematic reviews in engineering: A scoping review, [Online]. Available: https://osf.io/de3mq/ (visited on 04/09/2020).

[13] National Academy of Engineering. (2020). Engineering sections, [Online]. Available: https://nae.edu/166166/Sections (visited on 03/18/2020).

[14] M. Ouzzani, H. Hammady, Z. Fedorowicz, and A. Elmagarmid, “Rayyan—a web and mobile app for systematic reviews,” *Systematic Reviews*, vol. 5, no. 1, Dec. 2016. DOI: 10.1186/s13643-016-0384-4.

[15] B. J. Shea, B. C. Reeves, G. Wells, M. Thuku, C. Hamel, J. Moran, D. Moher, P. Tugwell, V. Welch, E. Kristjansson, and D. A. Henry, “AMSTAR 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both,” *BMJ*, vol. 358, Sep. 21, 2017. DOI: 10.1136/bmj.j4008.

[16] R. L. Diekemper, B. K. Ireland, and L. R. Merz, “Development of the documentation and appraisal review rool for systematic reviews,” *World Journal of Meta-Analysis*, vol. 3, no. 3, pp. 142–150, Jun. 26, 2015. DOI: 10.13105/wjma.v3.i3.142.