

An examination of the applications of Systematic Reviews in Engineering Education

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An Examination of the Applications of Systematic Literature Reviews in Engineering Education

Abstract

Systematic Literature Reviews (SLRs) are rigorous literature reviews designed to evaluate existing research comprehensively and transparently. They adhere to high standards comparable to primary research and are crucial for informing evidence-based decisions in research. Key elements include formulating a clear research question, detailing the authors' perspectives, and outlining the methods for identifying and appraising studies. Protocols for conducting systematic reviews are created by experts in their fields.

The purpose is to identify the major Engineering Education (EE) areas where SLR methodologies have recently been used.

Data were obtained from recent articles that use the methodologies of SLRs published in the 2023 and 2024 ASEE Annual Conferences. ASEE is a recognized leading professional organization in the field of EE. Data collected from the ASEE PEER document repository was verified in the Compendex database. The significant topical terms obtained from Compendex were the basis for an ontological iterative process of thematic analysis.

The results are presented in the forms of tables and topical maps showing six clusters: Education and Pedagogy; Engineering and Technology; Social and Cultural Dimensions; Mental Health and Behavioral Sciences; Data and Computational Technology; and Research Methodologies and Practices. Each cluster is presented with High Frequency Terms and Other Related Terms.

Introduction

It is well-known that Systematic Literature Review (SLR), a methodology for the analysis of subject literature, originated in the medical sciences as a tool for evidence-based decisions. For at least the last ten years, other disciplines including Engineering Education (EE) have begun to use this methodology. The following articles highlight the growing importance of SLRs in EE.

Borrego, M. et al. [1] introduced systematic reviews as a methodology to advance engineering education by synthesizing existing research and guiding future directions. The article discussed the importance of systematic reviews in critically appraising literature to inform practice and policy in EE. By conducting a review of systematic reviews published since 1990, Borrego identified gaps in the field and the potential benefits of applying systematic review methods in EE. The article concluded that systematic reviews could enhance theoretical development, research methodologies, and implications for practice within EE.

Power J. [2] explored the role of systematic reviews and meta-analyses in advancing EE by introducing Open Science principles. The author argues that EE, while rapidly evolving, faces challenges common to other disciplines, which have developed structures like Open Science to address these issues. The paper argued that SLRs, as a synthesis method, could act as catalysts

for the adoption of Open Science practices in EE. The strategic use of SLRs could help address challenges in synthesizing a growing body of research, particularly through practices such as pre-registration, open data, and explicit protocol reporting. Power's article suggests that implementing these practices would enhance the value of systematic reviews and support the development of EE as a discipline.

Phillips, et. al. [3] conducted a scoping review of EE SLRs and Meta-Analyses (M-A) to assess the extent of their application in EE and adherence to established reporting guidelines. The study examined 276 EE-related articles, finding a significant use of them, particularly, from 2015-2022. The focus is to determine the prevalence and quality of the methodologies used in SLRs and M-As studies in EE.

However, despite this growth, the authors emphasized the importance of following SLR and M-A guidelines to avoid presenting incorrect summaries due to missed evidence. They suggest including trained experts to improve the quality and accuracy of the reviews. The study also highlighted the need for improved reporting standards and adherence to the best methodological practices in the field.

On the topic of identifying current trends in EE, Katz, et al. [4] provided an overview of research topics and methods published in the *Journal of Engineering Education* (JEE) over a 20-year period. The report outlined trends in research topics, such as engineering learning mechanisms, learning systems, diversity, and assessment. It emphasized the importance of publishing research grounded in relevant theories, applying sound research methods, and addressing implications for policy and practice. The report also reviewed JEE's research agenda from 2006, which focused on areas like engineering epistemologies and learning mechanisms. This analysis is aimed at guiding future research and inspiring innovations in engineering education.

The articles included in this section underscore the need for rigorous, transparent methods to synthesize research and inform practice. Despite the growing use of these methodologies, adherence to best practices is often lacking, limiting the impact and reliability of the reviews. It is suggested that collaboration with trained experts could enhance the quality and effectiveness of SLRs in EE. As the field continues to evolve, embracing these strategies will be essential for advancing both theoretical and practical developments within engineering education [1].

The purpose of this study is to identify current major applications of SLRs in EE using data collected from the papers presented at the American Society of Engineering Education (ASEE) in two of the recent annual conferences, 2023 and 2024. It is important because ASEE is exclusively an engineering education society and papers in conferences report the most recent trends.

Methodology

We have used recognized bibliographic analysis techniques based on searching appropriate databases, followed by a meticulous examination of the results. The process used in this work agrees with, for example, the Passas, L. [5] definition of bibliometric analysis as “systematic study carried out on scientific literature for the identification of patterns, trends, and impact

within a certain field. Major steps include data collection from relevant databases, data cleaning and refining, and subjecting data to various bibliometric methods—an ensuing step in the generation of meaningful information.” Also, Ellegaard, O. & Wallin, J.A. [6] produced an extensive study in the prestigious journal *Scientometrics* on the impact of bibliographic analysis on scholarly production with emphasis on STEM fields.

The data was collected using two databases. The Proceedings of the ASEE conferences and the Compendex (Elsevier) database.

Searching in ASEE PEER.

ASEE PEER is the database of Proceedings of the ASEE conferences, <https://peer.asee.org/> . The Advanced search mode was used. The term “systematic reviews” was searched for in the Title field, and in the Document Collection field: 2024 ASEE Annual Conference & Exposition was selected. It produced 32 papers. To verify the validity of the records obtained, the abstract of papers are available and if necessary, the papers can be downloaded for reading and further examination. The same process was used to obtain the number of papers in the 2023 ASEE Proceedings, in this case, 20 records were produced.

Searching in Compendex.

Compendex, formerly the Engineering Index, is one of the most comprehensive engineering literature databases covering journals, conference proceedings, dissertations, standards, books, and recent preprints, from 89 countries, and holds more than 20 million citations.

The keyword “systematic reviews” was searched for in Compendex in the fields: Subject/Title/Abstract; this term was combined (using an added box with the AND operator) with the term ASEE or ASEE and the year. When the “NOT FIE” limit was added, it produced 258 records without specifying the year. After examining each citation, 181 qualified as SLRs. In Compendex, the keyword ASEE limits the search to the ASEE Annual Conference and Exposition. The following table shows number of citations from 2010 to 2024.

Table 1. SLRs published in the Proceedings of the ASEE since 2010.

Year	Count	Year	Count	Year	Count
2024	36	2019	15	2014	1
2023	20	2018	12	2013	3
2022	21	2017	13	2012	5
2021	12	2016	9	2011	1
2020	19	2015	14	2010	0

This table shows that from 2010 to 2024, 181 SLRs have been published in the Proceedings of the ASEE.

More specifically, for 2023, 60 citations show in the initial results, of those, 20 citations were qualified as SLRs from the 2023 Proceedings of the ASEE; the other 40 were from other publications. For 2024, 50 citations show in the initial results, of those, 36 citations were

qualified as SLRs from the 2024 Proceedings of the ASEE; 14 were from other publications. The 56 SLRs during 2023 to 2024 represent 31 percent of the total published.

ASEE PEER was the original data collection, but it doesn't provide a complete bibliographic record. Compendex was used to verify the citations from ASEE PEER and to capture the complete bibliographic records that include keywords and subject terms.

Ontological approach.

As proposed by Thomopoulos, R. et. al. [7], our approach to interpreting the ontology of the Compendex terminology (subject indexes) is *collaborative* (using the expertise of the authors), *iterative* (having cyclical attempts to understand the terminology) and *hybrid* (based on data and knowledge). This process includes: 1. Identifying key themes, 2. Using Frequency or significant thematic value, and 3. Prioritizing ontological connections. Comprehensive discussions about ontological methodologies are found in [8] and [9].

Results

Fifty-six papers published in the 2023 and 2024 ASEE Proceedings were found to qualify as systematic literature reviews. Each bibliographic citation has the following sections containing significant keywords: Main heading, Controlled terms, Uncontrolled terms, and Classification code.

This is an edited version of a bibliographic record for Compendex:

Title: Narrative Inquiry in Engineering Education: A Systematic Literature Review

Main heading: Engineering education

Controlled terms: Data acquisition - Engineering research - Paper - Population statistics - Search engines - Students

Uncontrolled terms: Narrative inquiries - Narrative theory - Personal perspective - Qualitative research - Qualitative research methods - Student experiences - Systematic literature review - Systematic Review - Undergraduate

Classification code: Computer Software, Data Handling and Applications - Data Processing and Image Processing - Pulp and Paper - Education -

The 315 topical terms collected from the Compendex citations were consolidated into one file and their frequency was determined.

Table 2. Keywords with high frequency of 3 or more.

Behavioral research 3	Mental health 4
Cognitive systems 3	Professional aspects 6
Conference papers 3	Problem solving 5
Curricula 16	Professional aspects 6
Data acquisition 3	Requirements engineering 4
Economic and social effects 4	Research questions 8

Economics 3	Science education 3
Education 37	Science technologies 6
Emotional intelligence 3	Search terms 3
Engineering and mathematics 5	STEM (science, technology, engineering and mathematics) 6
Engineering education 39	Students 28
Engineering education research 4	Student experiences 3
Engineering Professional Aspects 8	Systematic literature review 25
Engineering research 39	Systematic Review 14
Information Dissemination 4	Teaching 14
Literature reviews 10	

Thirty-one keywords were identified with a frequency of 3 or more. These and other terms with ontological relationships, were the basis for a thematic analysis which produced six clusters: Education and Pedagogies; Engineering and Technology; Social and Cultural Dimensions; Mental Health and Behavioral Science; Data and Computational Technologies; and Research Methodologies and Practices.

Table 3. Clusters with High Frequency Terms, and Other Related Terms.

1. Education and Pedagogy High Frequency Terms: Education (32), Curricula (16). Teaching (14), Systematic Review (25), Students (28). Other Relevant Terms: Educational context, Student engagement, Student outcomes, Teaching practices, Undergraduate students, Higher education institutions, Middle school, Engineering pedagogy.
2. Engineering and Technology High Frequency Terms: Engineering education (39), Engineering research (39), Professional aspects (6), STEM (6) Other Relevant Terms: Aerospace engineering, Artificial intelligence, Engineering fields, Safety Engineering, Design challenges, Traditional engineerings.
3. Social and Cultural Dimensions High Frequency Terms: Social Sciences (7), Cultural identity, Inclusivity need, Social media, Social identity, Underrepresented minorities. Other Relevant Terms: Black, Latin, and Indigenous students, Inclusion and exclusion, Women in engineering, Diversity in STEM.
4. Mental Health and Behavioral Science High Frequency Terms: Mental health (4), Behavioral research (3), Emotional intelligence (3), Anxiety, Depression. Other Relevant Terms: Trauma, Stress analysis, Coping strategies, Well-being.

5. Data and Computational Technologies

High Frequency Terms: Data acquisition (3), Data Handling and Applications (2), Artificial intelligence technologies, Deep Learning.

Other Relevant Terms: Machine-learning, Computational Thinking, Database systems, Large language models.

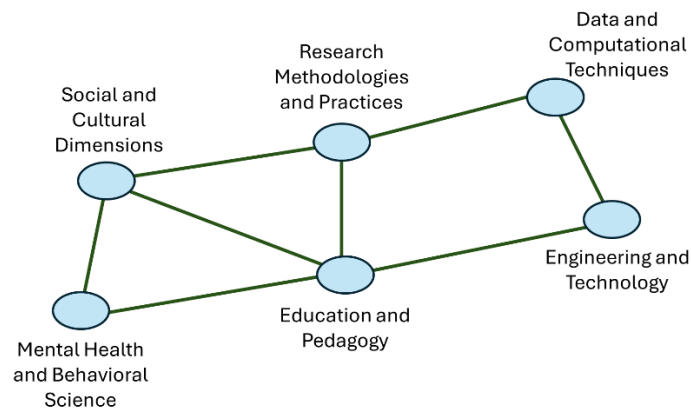
6. Research Methodologies and Practices

High Frequency Terms: Systematic literature review (25), Research questions (8), Literature reviews (10).

Other Relevant Terms: Qualitative research, Quantitative method, Conference papers, Experimental learning.

Using an ontological process, six major clusters have been identified.

Figure 1. Visualization of the Clusters.



Using a Python procedure, the six clusters are mapped with thematic connections or relationships. Figure 1 shows the cluster Education and Pedagogy with the strongest thematic connections of 4.

The Python procedure is utilized to visualize clusters of bibliographic data. This is the summary of the procedure used: With the data provided from Table 3, the data was imported, a co-occurrence matrix was constructed, the K-means clustering method was selected, a network graph was created where nodes represent the subject terms and links represent the relationships, and a scatter plot was produced.

When conducting a SLR, the process of identifying and analyzing clusters of high-frequency terms is valuable in several ways. These clusters represent key concepts, themes, or research areas that have been frequently addressed in the existing literature. There are many advantages of analyzing clusters with high-frequency terms. In summary, clusters of high-frequency terms are instrumental in SLR because they help organize the literature, identify key trends, and reveal important relationships between concepts. This process enhances the review's efficiency, rigor, and transparency, providing a solid foundation for further research and discovery. By leveraging

these clusters, researchers can synthesize findings, guide future studies, and uncover insights that might otherwise remain obscured in a large body of literature.

Conclusions

This work-in-progress study has created a mapping of significant topics in EE where SLR methodologies have been used. The subject terms Economics, Students, Search engines, and Teaching are very general and will require more examination of their meaning.

This project also corroborates with the results from previous studies [1], [2], and [3] of the increased interest by engineering educators in incorporating SLR methodologies in education research.

The limitation of this study is that the coverage of the literature is based only on current publications of the 2023 and 2024 Proceedings of the ASEE conferences. More comprehensive coverage will produce better insights into the use of SLRs as a tool to analyze the literature of engineering education. Appendix 1 shows the titles of the 56 papers selected.

Further, according to Noy, N. F., & McGuinness, D. L. [8], the process of developing an ontology is subject to multiple variants, and therefore the outcome is not always the ideal solution. Therefore, the interpretation of ontologies, in this case the Compendex subject indexes, offers several options; the authors made a good effort to provide the best possible results.

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Appendix 1: Titles of papers included in this project.

1. Narrative Inquiry in Engineering Education: A Systematic Literature Review.
2. Story-Driven Learning in Higher Education: A Systematic Literature Review.
3. A comparison of shared mental model measurement techniques used in undergraduate.
4. A Systematic Review of Instruments Measuring College Students' Sense of Belonging.
5. Use of Transfer Student Capital in Engineering and STEM Education: A Systematic Literature Review.
6. First-Year Students in Experiential Learning in Engineering Education: A Systematic Literature Review.
7. Exploring the Use of Social Media in Engineering Education-Preliminary Findings from a Systematic Literature Review.
8. Conceptualizing Social Justice in Civil Engineering and Professors' Perspective: A Systematic Literature Review.
9. Systematic Literature Review on Organizational Resilience in the Context of Higher Education Institutions
10. What Challenges Affect Arab Women's Engagement in STEM Fields, Particularly.
11. A Systematic Review of Academic Self-Concept Measures in First-year Engineering Education.
12. A Systematic Literature Review Examining the Impacts of Integrating Computer Science in K-5 Settings.
13. Board 111: A Systematic Review of Instruments Used to Evaluate the Effectiveness of the Entering Mentoring Curriculum.
14. Work in Progress: A Systematic Literature Review of Engineering Education in Middle School Classrooms.
15. Twenty-Four Hours in a Day: A Systematized Review of Community College Engineering Students with Outside Responsibilities.
16. Board 192: Identifying and addressing the barriers to advancement for women in the engineering professoriate: A systematic review of literature.
17. Work in Progress: A Systematic Literature Review of Person-Centered Approaches and Data-Driven Methods in Engineering Education Research.
18. A systematic review of pedagogical tools, learning goals, and participation strategies for high-achieving engineering and STEM students.

19. How to Develop Engineering Students as Design Thinkers: A Systematic Review of Design Thinking Implementations in Engineering Education.
20. Bridging the Gap: The Impact of Social Media on Modern Engineering Education-A Systematic Literature Review.
21. (Board 50/Work in Progress) A Systematic Review of Embedding Large Language Models in Engineering and Computing Education.
22. The Graduate Student Role in Undergraduate Research Mentoring: A Systematic Literature Review.
23. Predictors and Mediators of Conceptual Change: A Systematic Literature Review.
24. Exploring Intervention Research in Statics Courses: A Systematic Review of ASEE Publications from 2013 to 2023.
25. Learning Goals in Middle School Engineering: A Systematic Review and Comparison with NGSS and ASEE Frameworks (Fundamental).
26. Systematic Review of Intervention Strategies in Introductory Circuits Education: Insights from ASEE Conference Papers from 2014 to 2023.
27. Organizational Resilience in the Context of Higher Education Institutions: A Systematic Literature Review.
28. Racialized Trauma for Black, Latin, and Indigenous Engineering Students: A Systematic Literature Review.
29. Faculty and Administrators' Servingness in Engineering Education at Hispanic Serving Institutions: A Systematic Review.
30. Breaking the Stigma: Fostering Mental Health Resilience in Engineering-A Systematic Literature Review.
31. Culturally Relevant Practices at Hispanic Serving Institutions: A Systematic Review of Engineering.
32. Exploring the Use of Artificial Intelligence in Racing Games in Engineering Education: A Systematic Literature Review.
33. Supporting Undergraduate Engineering Students Who Are Primary Caregivers to Children: A Systematic Literature Review.
34. Summer Bridge Programs for Engineering Students: A Systematic Literature Review.
35. Teaching Online Engineering: A Systematic Literature Review.
36. Engineering Self-Efficacy and Spatial Skills: A Systematic Literature Review.
37. A Systematic Literature Review of Racialized Stress, Distress, and Trauma for Black, Latin, and Indigenous Engineering Students.
38. Inclusive Teaching Practices in Engineering: A Systematic Review of Articles from 2018 to 2023.
39. Wellbeing of Graduate Engineering Students: A Systematic Review.
40. [Work-In-Progress] A Systematic Review of S-STEM Programs in Community Colleges: Program Features and Student Decision-making.
41. Methodologies for Evaluating the Impact of STEM Outreach on Historically Marginalized Groups in Engineering: A Systematic Literature Review (Other, Diversity).
42. Quantifying Spatial Skills across STEM Disciplines: A Systematized Literature Review of Assessment Tools.
43. How AI Assisted K-12 Computer Science Education: A Systematic Review.
44. Visuospatial and Embodied Cognition in STEM Education: A Systematic Literature Review.
45. Use of Theories in Extended Reality Educational Studies: A Systematic Literature Review.

46. Board 150: Systematic Review of the Design Fixation Phenomenon at the K-12 Engineering Education (Other).
47. Board 165: K-12 STEM Teachers' Perceptions of Artificial Intelligence: A PRISMA-tic Approach (Work-in-Progress).
48. An Ecosystem Analysis of Engineering Thriving with Emergent Properties at the Micro, Meso, and Macro Levels.
49. Unmasking Cognitive Engagement: A Systematized Literature Review of the Relationships Between Students' Facial Expressions and Learning Outcomes.
50. A Systematized Literature Review on Workforce Development Programs for Engineering Graduate Students.
51. A Systematized Literature Review of Mental Health and Racial Battle Fatigue in Early-Career Black Engineers.
52. A Systematized Literature Review on Problem-Solving in STEM Education Exploring the Impact of Task Complexity on Cognitive Factors and Student Engagement.
53. Exploring Generative AI and Natural Language Processing to Develop Search Strategies for Systematic Reviews.
54. Generative Artificial Intelligence in Undergraduate Engineering: A Systematic Literature Review.