Work In Progress: A Scoping Review of Social Network Analysis Methods in Engineering Education

Introduction

In undergraduate engineering education, interactions between students are an important aspect of the learning environment. From a situated epistemology, knowledge is distributed among individuals. Increasing the connections between individuals generally increases the access everyone has to other individuals' knowledge. In the engineering education context, the educators' ability to understand how interactions between students are formed and persist has the potential to offer valuable insights into enhancing the learning experience overall [1].

To understand how interactions relate to engineering students' outcomes, researchers are increasingly deploying a method called Social Network Analysis (SNA). SNA examines the relationships and interactions between individuals or groups to provide an understanding of social structures and behaviors. Research applying SNA helps researchers understand engineering student interactions and has shown that students who have more connections with other students or have stronger connections to other students, demonstrate higher performance on engineering assessments than peers with fewer or weaker connections [2].

Important concepts in SNA include nodes, edges, and SNA measures. In SNA, *networks* are the collection of individuals and connections a researcher wants to study. *Nodes* are individual entities in the study network and can be people or groups. *Edges* represent connections between the nodes such as communications between individuals or groups. Researchers typically analyze networks through visual or quantitative methods. *Sociograms* are visual representations of the network and allow researchers to identify unanticipated trends in a network. For quantitative analysis, researchers develop *SNA measures* or concise descriptions of node traits. One example of an SNA measure is *degree centrality*, which sums the in- and out-going connections at a node. Degree centrality can help researchers identify the most connected nodes and provide insights into the influence of each node in the network. Overall, SNA gives a visual and quantitative description of a network for researchers to understand students' relationships, and how these relationships can influence outcomes [4].

With researchers continuing to consider and use SNA in engineering education, we propose there is a need to understand the current extent of literature regarding SNA in the engineering education context. Identifying the current extent of this literature will allow researchers to understand the status of SNA methods in engineering education and identify key areas for future full systematic reviews. This and future systematic reviews may inform future study designs and highlight gaps in the existing body of research. The goal of this work-in-progress study is to explore how SNA in prior literature has provided value for researchers studying engineering student interactions. To accomplish this goal, we first developed the following Research Questions (RQs):

RQ1: What is the current breadth of SNA in engineering education?

> **RQ1-A:** What SNA data collection, consolidation, and analysis techniques have been applied in engineering education research?

RQ1-B: What other methods have been applied in engineering education studies that included SNA techniques?
RQ1-C: What fields are applying SNA in the engineering education context?

RQ2: What phenomena in engineering education has SNA proven useful for understanding?

RQ2-A: Which SNA-based contrasts have identified significant results?
RQ2-B: Which SNA-based contrasts have identified non-significant results?
RQ2-C: What are the primary limitations of SNA in engineering education research?

With these RQs in mind, we identified a scoping literature review as the most fitting methodology.

Methodology

To answer our RQs, we applied a scoping literature review methodology. A scoping literature review offers an initial evaluation of the extent of the current literature on a specific topic and identifies the depth of that research. Identifying the scope and depth of prior research is helpful for researchers to highlight gaps in existing bodies of research, determine if one or more systematic reviews are necessary, and identify trends in the existing literature [5].

The first step in our scoping review process was to conduct an initial search through Google Scholar, ERIC, Education Source, and Scopus. This initial search aimed to identify relevant works which could validate our final search terms, and to see if a similar review had already been conducted. The initial search included the keywords: *social network analysis*, *network analysis*, *social network, network*, *engineering*, *education*, *classroom, faculty,* and *students*. Our initial search did not identify any reviews of SNA in the engineering education context. However, we did identify several related reviews [6]-[9]. These other reviews included studying SNA in education research [6], the use of SNA in technology-enhanced learning [7], and the application of SNA to online environments [8,9].

During the initial search, we recorded our search terms, the search strategies in similar reviews, and kept memos of successful and unsuccessful searches to inform our final scoping review keyword search. Further, the initial search process included identifying several papers for search validation, and search terms. Specifically, we selected several papers that met our search criteria [10-14] and required that these papers were within the final search results.

After finishing the initial search, we met with a university librarian for an expert appraisal of the search terms and to identify search databases. The librarian suggested we use ERIC, Education Source, and Scopus because these databases together include most engineering education journals and conference proceedings. Through our conversations with the librarian and checks for the papers we identified prior that should be in the review, we refined our final scoping review keyword search to:

({social network analysis} OR "network analysis" OR {social network} OR {Network Centrality}) AND (classroom OR education OR students OR faculty) AND (Engineering).

This keyword search result yielded 3197 papers across all three databases. After our final scoping review keyword search, we removed papers that were works-in-progress, books/book chapters, editorials, reviews, notes, short surveys, dissertations, letters, and conference reviews. We analyzed the titles, abstracts, and full papers (in progress) according to our final inclusion and exclusion criteria. We developed the inclusion/exclusion criteria to ensure that we included all relevant works to answer the RQs and removed those that were not relevant (i.e., papers either did not apply SNA or did not include primary research in the engineering education context). We present the inclusion/exclusion criteria here as only the inclusion criteria because all exclusion criteria were antitheses of one or more inclusion criteria. The final Inclusion Criteria (IC) are:

IC1: The study must be written in English.
IC2: The study must be a primary source.
IC3: The study must be published in 2022 or earlier.
IC4: The study must undergo a peer-reviewed, refereed publishing process (this includes conference papers and journals).
IC5: The study must apply Social Network Analysis methods. Specifically, the paper must:

- explicitly reference SNA as a part of the study methods, or
- apply network theoretic concepts to social interactions, i.e., represent interactions between individuals as matrices and/or graphs.

IC6: The study must be within the engineering education context. "Engineering" related is left to the judgment of the paper authors. Given that, the study sample must include one or more of the following:

- undergraduate or graduate engineering students, or
- engineering educators.

Our full paper identification according to the PRISMA [15] standard for a literature search and appraisal process is presented in Figure 1.

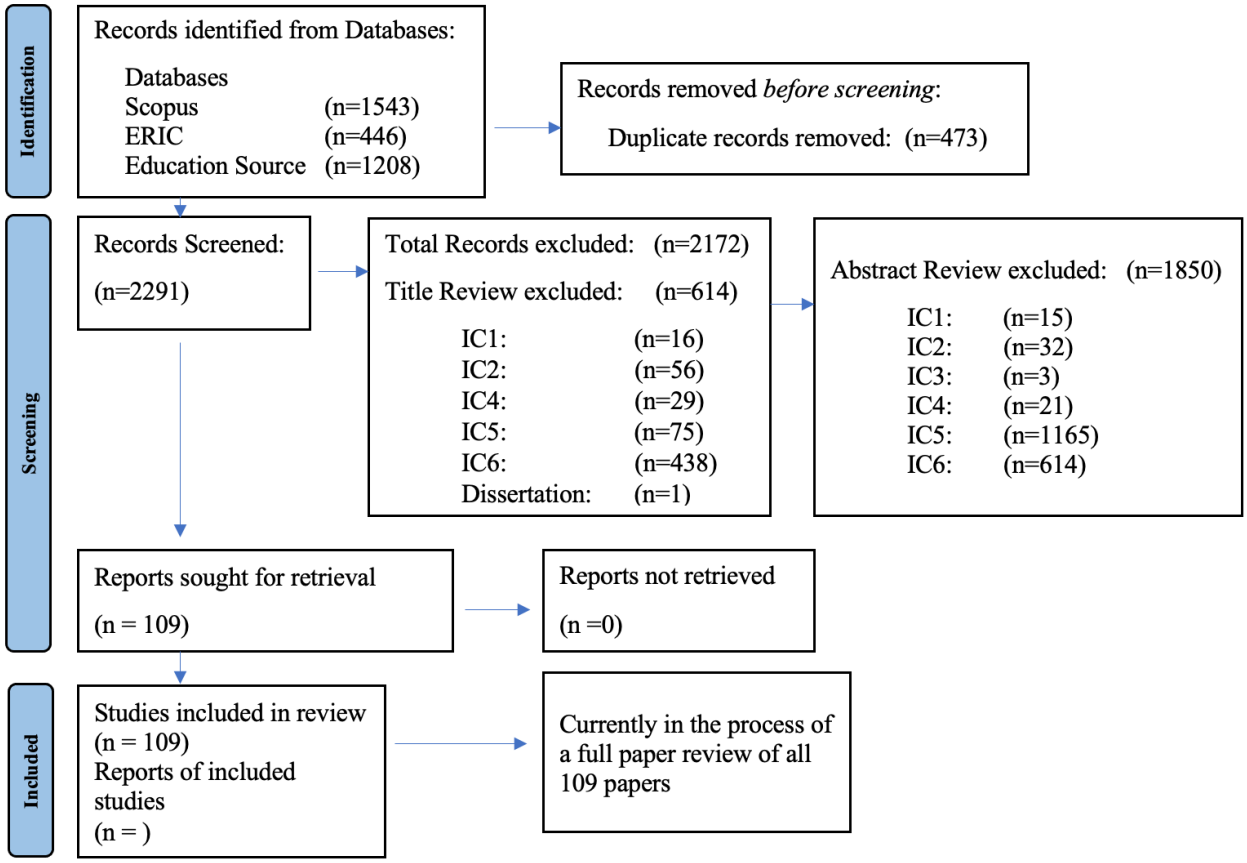

Figure 1. PRISMA flow Chart of final scoping review search and appraisal process.

As shown in Figure 1, our review identified 473 duplicate entries in the initial database results. For the title screening, we gathered all the database search results and prepared a table for recording which studies met our inclusion and exclusion criteria from the title to the final paper stage. Each of the two reviewers independently coded the papers at each stage of the process. After each stage (i.e., title, abstract, and full paper,) was complete the reviewers identified any differences and discussed these papers until a consensus was reached. We are currently in the process of finalizing the full-paper screening of the 109 papers.

Results

To identify the trends in full-paper review studies, we began by plotting the number of papers vs. publication year. Our findings indicate that research applying SNA in engineering education has generally increased over time as shown in Figure 2. It also shows that the first study using SNA in engineering education was published in 2001, illustrating the “newness” of SNA as an engineering education research method.

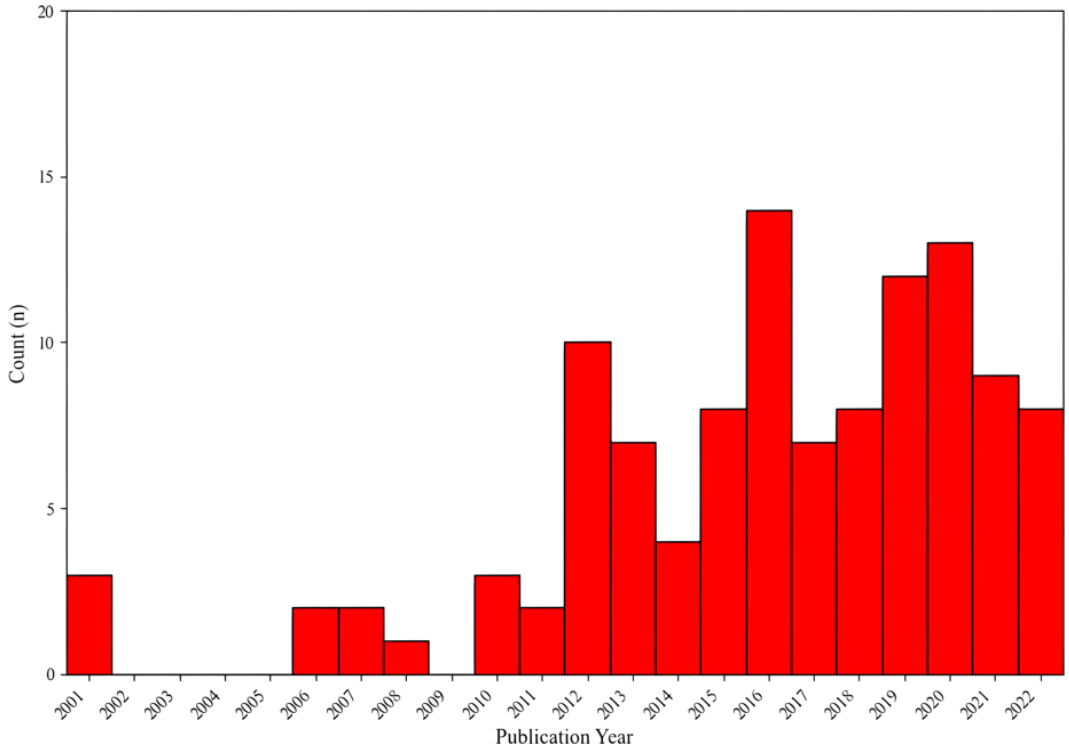

Figure 2. Chart of Publication Year versus Count (n)

To identify the research areas of those conducting SNA and publishing on SNA in engineering education, (RQ1-C), we divided the full paper review studies according to conference or journal papers, then the publication "discipline." Specifically, we coded publication venues in either pure education (e.g., the *Journal of Higher Education* which focuses on research in education), or pure science (e.g., J*ournal of Computational and Theoretical Nanoscience* where the main research focus is science and math), and then combined education and science. We excluded the five papers that did not fall into one of the three categories from Table 1.

Table 1
Publication Venue Type

Publication Type	**Publication Venue Type**			
	Pure Education	**Engineering Education**	**Pure Engineering/ Sciences**	**All**
Conference Proceedings	1	47	8	57
Journal Article	11	13	8	32

As shown in Table 1, most of the review conference publications were published in engineering education venues. However, the review journal articles are nearly uniformly distributed across pure education, engineering education, and pure science. These results may suggest that SNA is done at a smaller scale in engineering education studies, leading to an increase in conference proceedings, while the broader scope of journal articles encompasses a wider range of disciplines. This broader scope of journal articles shows the interdisciplinary nature of SNA research.

Future Work

In our future work, we will examine the results of the 109 papers according to our *a priori* codes described in Table 2. Our coding table will enable us to answer RQ1 and RQ2 by examining what SNA-based contrasts have been effective or not effective for prior researchers. Our coding table will also include the data collection and methods used to help answer RQ1-A and B.

Table 2
Coding table to examine the results of the 109 papers.

Code(s)	**Sub-code(s)**		
General Information	Title	Author(s)	Year of Publication
SNA Data Collection	Participants majors and sample size		Data collection methods (interviews, open-ended surveys, close-ended surveys, etc.)
SNA Techniques	SNA measures, non-SNA measures used for analysis, and contrast methods		Integration of SNA with other methodologies
Consolidation	Entity resolution and/or data consolidation techniques		Network visualization techniques
Significant Results	Statistically significant contrasts		Highlighted findings (according to study paper authors)
Insignificant Results	Contrasts which did not provide statistically significant results		Highlighted difficulties (according to study paper authors)
Limitations	Internal and external validity limitations (according to study paper authors)		Areas for future research

Conclusion

As engineering education continues to adopt new research methods, understanding the extent of these methods and the successes or failures of methods in prior work is increasingly important. In this work-in-progress scoping review, we have identified the need to do a review of SNA methods in engineering education. We then developed our inclusion criteria to ensure we found relevant works to answer our research questions. Following PRISMA [15] standards, we

identified 109 papers for the full paper stage of the search and appraisal process. Emergent findings from the full paper review studies include that SNA in an engineering education context is growing. We also discovered that the broader scope of journal articles shows the interdisciplinary nature of SNA research. In future work, we will complete a full review of the 109 review papers using an *a priori* coding table developed through reading similar reviews and targeting our research questions.

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