Effective Engineering Information Literacy Instruction: A Systematic Literature Review

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\textbf{ABSTRACT}

The objective of this study was to investigate effective methods of teaching information literacy to engineering undergraduate students. The authors searched several databases (e.g., Compendex, Scopus, ERIC) for English language studies published between January 2000 and January 2016 that contained both an information literacy intervention for engineering undergraduate students and an assessment method for evaluating the intervention's effectiveness. Thirteen studies were included in the final data set, of which eleven studies reported effective results based largely upon descriptive statistical analysis. The strongest indicator of effectiveness that emerged in the data was collaboration with disciplinary faculty. With few articles in the final results set containing inferential statistics, the authors were only able to draw limited conclusions regarding effectiveness. The low use of such statistical methods highlights a need for librarian researchers to develop skills with research design and statistical analysis. This study is one of few systematic reviews on the topic of information literacy and the first systematic review on engineering information literacy effectiveness. It intends to serve as a baseline for future work.

\textbf{Introduction}

What are effective ways of teaching information literacy to engineering undergraduate students? There is an existing body of literature exploring the multiplicity of different initiatives undertaken by engineering-focused librarians, from alternative instructional delivery methods to innovative in-class activities (many of these initiatives mirror information literacy strategies used by librarians in all disciplines), which attempts to answer this question on a case-by-case basis. However, in a world where academic subject specialist librarians serving STEM subject areas have limited time and resources, determining which instructional practices can have the largest impact is vitally important. This study attempts to find answers to this research question through the systematic literature review process.

The literature on engineering information literacy (EIL) is diverse in scope, content, and method. The idea of educating engineering students about the field's literature has roots dating back to at least the 1890s (White, 2016). Presentations at early meetings of the Society for Promotion of Engineering Education (the predecessor of the American Society for Engineering Education or ASEE) described the need for training in technical literature indices, to help students cope with the volume of information available (Hyde, 1948). As the organization's Engineering Library Division (ELD) evolved over the next century, engineering librarians expanded their focus to incorporate new technologies and new pedagogies into the practice of information literacy instruction (White, 2017). At a recent ASEE annual conference, ELD members presented papers on topics such as curriculum mapping (McAdams & Glauberman, 2017), mentoring (Melgoza, 2017), data management instruction (Misch, Wiley, Schlembach, & Imker, 2017), open educational resources (Leachman & Anderson, 2017), and the effectiveness of video tutorials vs. guides-on-the-side in information literacy instruction (Zhang & Kozak, 2017).

Systematic literature reviews (SLRs) are a form of literature review defined by their rigorous, systematic methodologies. This style of review applies rigor to the searching, identification, sorting, and synthesis processes, in order to find the evidence to answer a specific research question (Petticrew & Roberts, 2006). While SLRs are often conducted by or with the assistance of librarians, in order to leverage the profession’s skill in information retrieval and management (Gore & Jones, 2015; McKibbon, 2006), they have only rarely been applied to the
library literature itself. There have been systematic literature reviews of the engineering education literature (notably Borrego, Foster, & Froyd, 2014) and of the information literacy instruction more generally (notably Koufogiannakis & Wiebe, 2006), but the confluence of the two has not previously been examined. The advantage of conducting a systematic review comes from the power of combining the results of many similar studies to see an overall pattern, rather than relying on the results of individual, smaller studies.

This systematic review of the engineering education literature was conducted between 2015 and 2018 by a group of four academic librarians with science, technology, engineering and mathematical (STEM) library backgrounds (e.g., liaison responsibilities), with the aim of determining the most effective practices of information literacy instruction aimed at engineering undergraduates. The motivation for conducting the review and the lessons learned from the SLR process have been previously discussed (Phillips, Van Epps, Johnson, & Zwicky, 2018); this paper presents the results and discusses how they relate to the aforementioned research question.

Methods

The aim of this study was to investigate effective methods of teaching information literacy to engineering undergraduate students. Using online resources, the researchers created a list of published articles and conference proceedings at the intersection of information literacy and engineering education literature. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist guided the literature searching and the data analysis (Moher, Liberati, Tetzlaff, Altman, & The PRISMA Group, 2009).

Information sources

A wide search of English-language written literature was performed using the following databases (platforms listed in brackets): ASEE PEER Document Repository, Compendex [Engineering Village], Education Resources Information Center (ERIC) [EBSCO], INSPEC [Engineering Village], Library and Information Science Abstracts (LISA) [Proquest], Library, Information Science and Technology Abstracts (LITA) [EBSCO], Library Literature and Information Science [EBSCO], Professional Development Collection [EBSCO] and Scopus. Although the exact search strings varied according to the specific features and subject headings of each database (see Table 1 for sample search strategies used in Compendex and ERIC), each search used the following concepts: information literacy, instruction, engineering, and undergraduate students.

Each of the resulting searches were filtered for the range dates of 2000–2016. All databases were last searched in January 2016. ERIC was limited to 2000–2015 because no results were found for 2015–2016.

Risk of bias across studies

Due the initial parameters identified, there are inherent limitations to the cumulative results. There are limitations with the keywords selected, as they are not inclusive of all of the possible “information literacy” synonyms and related terms. Additionally, there are articles excluded from the cumulative results due to the limited range of publishers and publications available in the databases selected. Author-supplied abstracts are also limiting because they may not utilize the controlled vocabulary of the field(s), which could affect inclusion or exclusion in searches. In addition, the authors’ limited their searching to papers written in English, which could have missed studies published on the topic in other languages.

Data selection

The final selection was achieved using three levels of article screening. For the first level of the screening, articles were screened and selected using their titles and abstracts. Each title and abstract was reviewed for scope and suitability for inclusion based on the study’s predetermined inclusion criteria, namely an engineering undergraduate student population, the presence of an information literacy intervention, and the presence of an assessment method for determining effectiveness. Unclear studies and studies that did not specify the student population or engineering context were not removed at this stage. The unclear studies were retained for the full-text review, when more detailed information was available for fully assessing the inclusion criteria.

The authors then retrieved the full text of the remaining articles. The second level of screening reviewed the full-text of those articles, using the same criteria as previous abstract review. Each study needed to present a well-articulated II component of the instructional plan, not simply a general instructional or disciplinary-specific intervention, and had to include an assessment. There were no limitations on which II topics were covered or not covered, but they had to be clearly information literacy topics. Topics considered included, but were not limited to, database selection, patent searching, and citation practices.

The authors then performed a third level of screening, for assessment quality. During this phase, the authors removed studies that did not include a clear (i.e., what the assessment instrument was, its timing) and full assessment of II learning (not only measuring student engagement or opinion; needs a control group, comparison group, or pre-set target of effectiveness). That is, the student deliverables (i.e., student artifacts/course submissions that were used to determine the effectiveness of the intervention) had to be clearly identifiable. In this stage, two members of the research team reviewed each article, and the entire research team would confer about inclusion for each title in cases where the initial reviewers disagreed. Article-level data was not confirmed with the original authors; instead, the researchers relied on the published records.

EndNote citation management software (http://endnote.com) was used for the collecting and sharing of articles in the first phase of review. Rayyan (http://rayyan.qcri.org), an online systematic review application, was used for the full text phase of screening. Rayyan provides a “one-stop” dashboard where collaborators can upload citations and full text documents and conduct their screening processes (Johnson & Phillips, 2018). Due to the technical and usability limitations of both applications, Google Sheets, Google’s free online spreadsheet application, was used for the third and final quality screening and for data extraction. The use of Google Sheets enabled real-time syncing and sorting based on inclusion criteria by the authors concurrently.

Data extraction

Once the screening was complete, the researchers analyzed the remaining, included articles and extracted specific pieces of data from each source. The data items targeted for extraction are listed and described in Table 2.

Results

Study selection

Fig. 1 shows the flow of information through the SLR, detailing the number of articles remaining at each stage of the process. In total, the authors located 1224 articles in their literature search. 305 of the articles were identified as duplicates and removed from the result set, leaving 919 items for the abstract level review. 797 articles were determined not to meet the inclusion criteria during the abstract review; removal of these items resulted in 122 articles for the full text review.
The authors determined 68 of the articles examined in the initial full text review clearly did not meet the inclusion criteria, leaving 54 articles to be assessed for quality. The authors then normalized their definitions of the inclusion criteria “effective” for this study and removed another 41 items, leaving 13 articles for the final result set. Table 3 provides the citations for articles included in the final dataset.

### Study characteristics

Using the previously identified data items targeted for extraction, the following list of study characteristics emerged:

- Delivery mode (face-to-face, online, both)
- Number of videos/modules (if online)
- Online videos/modules interactivity (Y/N)
- Stated collaboration with disciplinary faculty (Y/N)
- Description of pedagogical technique (e.g., single lecture, multiple lectures, problem-based learning)
- IL topics covered (e.g., general IL, copyright, plagiarism, citation)
- Student population (e.g., first-year engineering, senior capstone)

### Table 2

Data items targeted for extraction

<table>
<thead>
<tr>
<th>Category</th>
<th>Data item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instructional elements</td>
<td>Delivery mode</td>
<td>Setting by which instruction took place (e.g., face to face, hybrid, or online)</td>
</tr>
<tr>
<td></td>
<td>Number of videos</td>
<td>Quantity of recorded or digitally produced instructional content</td>
</tr>
<tr>
<td></td>
<td>Interactivity</td>
<td>Presence of recorded or digitally produced instructional content that requires user responses</td>
</tr>
<tr>
<td>Classroom elements</td>
<td>Collaboration</td>
<td>Created instructional content is the result of communication between the disciplinary faculty and those creating and delivering the information literacy content</td>
</tr>
<tr>
<td></td>
<td>Pedagogical technique</td>
<td>Scenario in which the educational intervention occurs (e.g., active learning)</td>
</tr>
<tr>
<td></td>
<td>IL topic covered</td>
<td>Specific subject/subjects within IL paradigm covered by instruction</td>
</tr>
<tr>
<td></td>
<td>Student population</td>
<td>Makeup of participants in the course studied, including year of study and major</td>
</tr>
<tr>
<td></td>
<td>Type of engineering course</td>
<td>Major or department with the engineering curriculum</td>
</tr>
<tr>
<td></td>
<td>Type of course artifact</td>
<td>Student deliverable that was used to assess effectiveness of IL instruction</td>
</tr>
<tr>
<td>Setting elements</td>
<td>Department</td>
<td>Department that houses the course (e.g., English, mechanical engineering, chemical engineering)</td>
</tr>
<tr>
<td></td>
<td>Publication date</td>
<td>Date the article became publicly available</td>
</tr>
<tr>
<td></td>
<td>Presence of IL intervention</td>
<td>Occurrence of a classroom intervention</td>
</tr>
<tr>
<td>Criterion elements</td>
<td>Presence of assessment</td>
<td>Occurrence of a measure of effectiveness</td>
</tr>
<tr>
<td></td>
<td>Intervention</td>
<td>Teaching action or interference with an information literacy focus that provides proof of learning and teaching</td>
</tr>
<tr>
<td></td>
<td>Assessment</td>
<td>Tool, measurement, or mode of evaluation</td>
</tr>
<tr>
<td></td>
<td>Effectiveness</td>
<td>Reached intended result; successful; positive relationship with learning</td>
</tr>
</tbody>
</table>
Synthesis of results

Publication venues and dates of publication

As shown in Table 3, the majority of the studies (9 out of 13, or 69%) are conference papers published in the ASEE Annual Conference proceedings. The other four studies are journal articles published in engineering education (Journal of Engineering Education) or library and information science journals (Journal of Academic Librarianship, College & Research Libraries, Innovation). Additionally, two of the studies (15%) were published between 2000 and 2005, five studies (38%) between 2006 and 2010, and six studies (46%) between 2011 and 2015.

Delivery modes

Eight out of 13 (62%) of the studies in the final results set were delivered through face-to-face instruction, three (23%) through online instruction, and two (15%) involved both face-to-face and online instruction. Three out of the five studies that utilized online instruction (either alone or in combination with face-to-face instruction) incorporated interactivity into the online modules. Additionally, three out of five studies that involved online instruction described delivering the content through a single module or video, while the other two studies discussed multiple videos/modules (one of these studies incorporated six videos/modules and the other four videos/modules).

Table 3

<table>
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<th>Citation</th>
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Collaboration with disciplinary faculty

Nine of the 13 studies (69%) describe collaborating or consulting with disciplinary faculty on the content of the IL instruction.

Pedagogical methods

The authors categorized the primary pedagogical methods utilized in the studies as shown in Table 4. This approach is based on Koufogiannakis and Wiebe's (2006) teaching methods categorization presented in their IL-focused SLR. Traditional instruction was inferred if the authors described face-to-face delivery modes but did not state or discuss their methods in accordance with the active learning definition used for this SLR. If multiple pedagogical methods were utilized in a study, the experimental condition and/or most dominant mode is reported as the “primary” pedagogical method used.

The most frequently reported pedagogical method used was traditional instruction, such as database demonstrations and lecture-based sessions (six studies, or 46%). CAl (i.e., online tutorial modules) was
utilized in four of the studies (31%). Active learning methods, such as problem-based learning, were used less frequently (two studies, or 15%). The least frequently reported method was SDIL. One study (8%) described using SDIL methods, which included the incorporating online web guides (analogous to Libguides) into courses for students to utilize independently in locating resources for class assignments.

**IL topics covered**

The IL topics covered in the interventions described in the SLR studies were classified by the authors as primarily general (e.g., searching for books in the library, citation) or technical/subject focused, where the intervention was heavily centered around topics and context related to engineering information needs (e.g., engineering focused databases, technical standards). Eight of the studies (62%) focused mainly on general topics, while five (38%) were technical/subject-focused.

**Course type**

Table 5 details the types of courses represented in the studies in the final results set of this SLR. Five of the studies (38%) focused on first year introduction to engineering/engineering design courses. Two studies (15%) focused on senior design or capstone courses (one mechanical engineering and one electrical and computer engineering), and two studies (15%) worked with other undergraduate engineering design courses (all majors sophomore design, mechanical engineering junior design). Two studies (15%) examined a mix of engineering courses. One study (8%) focused on engineering students in a non-engineering course (an introductory oral communication course) and one study (8%) did not specify the course type in which the IL intervention took place.

**Student deliverables**

Six of the studies (46%) in the final results set examined student assignments, such as a bibliography or report. Another six studies (46%) analyzed pre-post test results from the IL intervention(s). One study (8%) compared project grades between student teams who experienced the intervention to a control group.

**Effectiveness of intervention**

Table 6 provides a summary of the effectiveness of the interventions in the SLR studies, as well as whether the authors used descriptive (e.g., comparison of averages) or inferential statistics (e.g., paired t-test) for evaluating effectiveness. 11 out of 13 studies (85%) showed effectiveness, while one study (8%) demonstrated no difference between the experimental and control groups, and one study (8%) presented mixed results. 8 of the 13 studies (62%) utilized only descriptive statistics to evaluate the effectiveness of their IL intervention.

**Discussion**

Combining several of the tables of information above helped the researchers look more closely at the factors that are making a difference in the effectiveness of the information literacy instruction.

The analysis of the 11 effective articles does not yield insights different from looking at the full final set of 13 articles for the individual factors. Fig. 2 shows the preponderance of traditional, face-to-face lecture style teaching, which is not surprising since many librarians who are teaching are accustomed to this model and likely, it is still the most comfortable for many librarians. This could lead to thinking that the face-to-face lecture is the most effective. Since the researchers were not able to differentiate levels of effectiveness with the information provided in the articles, the frequency of face-to-face is more a reflection of preponderance of method than effectiveness. Similar to the
findings by Koufogiannakis and Wiebe (2006), traditional information literacy instruction is the most frequent IL method used, and often not studied comparatively with other teaching methods. Despite that, it is shown as an effective method when compared with no instruction, which is reinforced by our findings that are specific to the engineering information literacy literature.

Fig. 3 shows that all of the instruction using CAI in this result set was for teaching general information literacy topics. Upon reflection, this is not surprising, since learning the twists and turns of technical literature often requires a nimble response to students’ individual information needs, in the form of an in-person instructor. The same applies to active learning situations, which is similarly tied to face-to-face methods in these results. At the same time, general information literacy topics have been presented in online learning modules for years and shown to be useful at different universities (Donaldson, 2000; Tronstad, Phillips, Garcia, & Harlow, 2009). In addition, the work of Koufogiannakis and Wiebe (2006) found no effect difference between CAI and traditional instruction, so if CAI is used for technical IL instruction, it may be just as effective as face-to-face instruction.

Eight of the nine studies that included collaboration with the disciplinary faculty member were rated as effective, which emerges as the researchers’ clearest indicator of effectiveness. Fig. 4 shows how the different pedagogical methods align with the librarian collaborating with the disciplinary faculty member. Again, the preponderance is towards traditional teaching methods, which is not surprising since many disciplinary faculty members still teach this way, and it can be difficult to bring students into a new mode for a single class. Regardless of the teaching method, working with the faculty for the main class seems to positively impact the effectiveness of the information literacy instruction, perhaps because the ties to the class content are clearer and the information literacy topics have more context. This benefit of clear ties to course content is confirmed by the outcome found by Van Epps and Sapp Nelson (2013), that showed a just-in-time model of information delivery, with the library information tied closely with the timing of the related assignment, produced student work with more references that are scholarly and a greater variety of resources, rather than relying solely on websites. In addition, the Information Rich Engineering Design model (Fosmire & Radcliffe, 2014) was developed specifically to integrate different types of information discovery and use into the primary design model most engineering students are taught during their education, building on the strengths of connecting information to the discipline and immediate context as the best way to build skills and reinforce retention.

Limitations

The study includes several limitations. The study was started to establish a baseline for effective engineering information literacy, and selected a 15-year window of published papers for that purpose. During the course of this data analysis, additional papers on the topic have been published, which are not included. The authors elected to stay with the original publication window, rather than attempting to update the data, as the study fills a substantial gap in the literature and functions as benchmark. Since the body of engineering information literacy literature has not been previously reviewed, the current study will help future studies understand how teaching and assessment practices, and publications about them, have changed over time.

Additionally, during systematic reviews, it is possible for the researchers to contact the study authors to gather additional details that are not included in the papers. The authors of this SLR elected to limit the study to just the details provided in the published papers, which may have restricted the final set of articles more than would have happened with additional information. The level of research details that were required to meet the inclusion criteria for this study helped the researchers realize the number of studies published in the EIL literature without complete details on the method used, the data gathered, or the assessments conducted, was quite limited.

At least one paper the researchers expected to see in the dataset was not discovered with the search strings used, which highlights the challenge in designing a search that will find all the anticipated articles. For example, the Van Epps and Sapp Nelson paper (see Table 3) identified in the final results is a work in progress paper published at a conference, which includes only preliminary data testing the effectiveness of two different delivery frequencies. The full journal article (Van Epps & Sapp Nelson, 2013) that was published later and included the complete data analysis was not identified in the search. Upon further investigation, the researchers identified that Van Epps and Sapp Nelson refer to students, but don’t call out college students or undergraduates specifically, which was a required element in the search. As a result, the database indexing did not match with the inclusion criteria, and is likely why the article was not identified when searching LISA. Both LITA and Library Literature, the other databases searched which could have returned the missing article, do not include author supplied keywords in the record, and in both cases the information literacy term was not applied to the article by the database indexers, even though there are subject terms for IL in these databases. Given this known example, it is possible there are other relevant articles not included in this study due to poor database indexing. The same could also be said for documents not written in English, which were intentionally omitted from this study for practical considerations.

The SLR method has an accommodation to do what is referred to as “hand searching” to find additional papers for a study (Cochrane...
Training, 2017). Like the other searches, it is meant to be done at the beginning of the data discovery, not as a late addition in the process. Typically, hand searching is used to include content from publications that are known to be excluded from indexes or for very new areas of study where the indexing would not have caught up with new terms. Since the initial searches had returned 1224 articles, there was not a sense at that stage of the project that some items would not have been found due to indexing practices for different databases. Changing the SLR process part way through a study means starting from the beginning again to ensure the same treatment of add that data. The researchers chose to go forward with the set found in the initial searches, and use the limitations to be transparent about the process, and to help others learn some of the challenges in the SLR method.

Conclusions

When all the aforementioned factors are considered together, there is no clear answer to the questions of a most effective instruction method. Overall, the study found fewer articles than anticipated due to the criteria requiring an objective measure to determine effectiveness. There are additional studies that mention improvement in the student deliverables, but do not support the observation with a comparative assessment, or the assessment data is not shared in the paper. The SLR resulted in a very small number of EIL articles that include inferential statistics, as shown in Table 6, making it difficult to draw many conclusions, and impossible to move into the space of a meta-analysis. This finding again parallels a finding by Koufogiannakis and Wiebe (2006), where 20% of the studies identified did not include any statistical analysis, and an additional 10% mentioned that statistical analysis had been done, but did not report the data. The low use of inferential statistics highlights a need for librarian researchers to develop skills with research design and statistical analysis is reinforced when reading the 2017 Author Guidelines for Conference Papers (ASEE Engineering Libaries Division, 2017), which detail updated expectations for data analysis in quantitative empirical studies. This expectation also aligns with a call for Library & Information Science (LIS) programs and individual librarians to develop skills with statistics in support of ongoing information literacy research that has appeared repeatedly in LIS literature over last 20 years (Dilevko, 2007; Liebscher, 1998; Van Epps, 2012).

The literature of engineering information literacy is growing. The search strings were repeated in Compendex and Scopus in early 2018, the two databases that returned the most articles in the original search, and the researchers found 120 articles published in 2016 and 2017 that match the initial string. The same databases returned 649 articles for the 15-year span of 2000–2015, which is about half the initial results. This volume of publication could include as many as 600 items published in the next 5-year span (2016–2020) using the same search strings, which is about half as many articles in a third the publishing timeframe. In the future, it would be interesting to replicate this baseline systematic review EIL study to encompass the next 5 years of publication, and see if more publications are including measures of effectiveness to make determinations of statistically substantiated effectiveness of learning.

It is also worth noting, in our final set of papers, that most of them are conference papers, many of which were not further developed into journal articles. Within the engineering librarian community, this is possibly due to the requirement of publishing a paper to present at the ASEE annual conference, combined with many librarians not needing to publish peer reviewed journal articles as part of their job expectations. Self-imposed expectations of increased research rigor help build those skills within the library community. While conference papers reach a large portion of the engineering LIS community, strengthening the research of these papers and publishing more in the engineering education literature would reach more disciplinary faculty, and may help make connections and build more opportunities for effective librarian interventions in engineering classes.

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