Board 7: Engineering Libraries Division: Effective Methods of Engineering Information Literacy: Initial Steps of a Systematic Literature Review and Observations About the Literature

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Effective Methods of Engineering Information Literacy: Initial Steps of a Systematic Literature Review and Observations about the Literature

Abstract

Background – There is a body of information literacy (IL) literature applied to undergraduate engineering students, much of which discusses different methods for teaching, such as classes/one-shots, online tutorials, gaming, and other interventions. It is important for librarians to know which methods of teaching engineering information literacy (EIL) are most effective for student learning, in order to make efficient and effective use of student and librarian time.

Purpose/Hypothesis – The authors reviewed the existing literature to find indications of the most effective methods for teaching and/or integrating EIL, both in face-to-face and online instruction.

Design/Method – The authors have completed the first stages of a systematic literature review (SLR), through the creation of the final dataset. The initial searches generated a set of 1224 papers prior to duplicate removal. Duplicate removal and multiple rounds of review, using authors-created inclusion and exclusion criteria, narrowed the final dataset to 13 papers.

Scope/Method – The lessons learned in the process around searching, tools for data evaluation, and articulation of criteria are presented. As a result of this portion of the SLR process, the authors identified characteristics of the undergraduate-focused EIL literature that are shared.

Results/Discussion – A brief summary of the process to arrive at a final dataset of 13 papers, the challenges in the process, and the refinements made at each step are outlined.

Conclusion – There are several preliminary conclusions to be drawn, many of which will not be surprising to the engineering librarian community. The dataset came down to just 13 items because much of the EIL literature is based on student self-report data on how the class went, or was it enjoyable, rather than on actual student learning gains. As such, these papers did not meet the criteria for demonstrated learning gains as a measure of effectiveness. In addition, some papers were excluded for lack of clarity about methods. In these studies it is not evident how either the intervention and/or the assessment was conducted, with regard to timing, instrument used, etc. Some additional papers were excluded because a control or comparison group was not included to establish “effectiveness” of the intervention. Overall, the authors note the EIL literature frequently reports descriptive statistics, showing that data has been gathered, but sometimes falls short of a full analysis that allows the researchers to draw meaningful/well-grounded conclusions from the data.

Introduction

Systematic reviews are "rigorously designed and conducted literature reviews that aim to exhaustively search for, identify, and appraise the quality of and synthesize all the high-quality research evidence in order to answer a specific research question [1]." They differ from traditional reviews, where authors aim to summarize the literature of a particular topic without necessarily sharing the details of their processes or assessing the quality of the studies, in that they are a research method in themselves, designed to test hypotheses and answer research questions [2].

Librarians regularly participate in SLRs, whether as consultants, searchers, or co-authors [3], [4]. A recent emphasis on SLRs in engineering education led to the ASEE Engineering Libraries Division (ELD) co-sponsorship of a workshop on the topic at the 2017 ASEE Annual Conference and Exposition in Columbus, OH [5].

The authors, four STEM academic librarians, wanted to learn more about this current topic in the discipline of engineering education and experience first-hand the process of conducting an SLR related to engineering librarianship. They opted to explore a research question related to engineering information literacy (EIL), since educating engineering students about the literature of their field, a component of EIL, has roots dating back to the 1890's [6]. There is an existing body of literature in this area and it is important for librarians to know which methods of teaching EIL are most effective for student learning, in order to make efficient and effective use of student and librarian time. This paper shares the preliminary findings and lessons learned through conducting a systematic review to answer the research question - what are effective ways of integrating information literacy into undergraduate engineering education?

Background

SLRs are not a new topic. They have existed for over a century [4] and appear extensively in the literature over the past twenty years in the disciplines of medicine, social science, and education [1]. However, their emergence in the field of engineering education is a relatively recent development, occurring largely after Borrego, Foster, and Froyd's call for researchers in the discipline to "consider including systematic reviews in their repertoire of methodologies [7]."

In the area of IL instruction, there have been a handful of SLRs looking for instructional best practices. Typically, these are related to disciplinary information literacies of disciplines already invested in the systematic review method. Brettle [8] investigated best practices relating to the IL instruction (or "information skills training") of healthcare professionals. Jacobs et al. [9] systematically reviewed eHealth-based methods for improving health IL outcomes in patients. Business IL instruction was the focus of two SLRs by Ann Fiegen of Cal State San Marcos, with one study on research methods [10] and one study on conceptual models and the instructional practices themselves [11].

In education, and particularly relevant to this study, Koufogiannakis and Wiebe [12] conducted an SLR looking for instructional best practices in teaching information literacy skills to undergraduates, generally. They searched fifteen databases, found and sifted through 4,356 citations, and determined that 122 met their inclusion criteria (the instruction must be librarian-led, the subjects must be undergraduates, and the study must have an evaluative component).

Ultimately, they found that self-directed and computer-assisted methods looked promising, although they took a dim view of the state of the literature, specifically calling out the lack of validated research instruments in the articles evaluated.

Within the engineering education IL literature, we did not encounter any SLRs in the course of this study. That said, members of ASEE's ELD have produced several relevant reviews related to the history and publication output of the division. White [6], [13] detailed the history of the division, from 1893 to the present. While the bulk of the two papers is devoted to organizational details, there is some discussion of the material shared at the annual meetings. More relevant to this study are the analyses of the divisions' publications and related documentation. Hubbard [14] and Osorio & Solomon [15] performed bibliometric analyses of ASEE conference papers by members of the divisions, with the latter going so far as to map topics and vocabulary used in these documents with the Sci2 network analysis and visualization tool.

Methods

The authors went through established SLR processes of identification, screening, eligibility, and inclusion, as outlined by Moher, Liberati, Tetzlaff, Altman, and the Prisma Group [16]. Figure 1 in the *Results* section illustrates the details of the number of articles remaining after each of the stages for this study.

Identification

Identification consisted of selecting and searching a collection of databases to catalog the intersection of IL and engineering education literature to achieve the objective of analyzing effective methods of integrating IL in undergraduate engineering education courses. Table 1 describes the databases searched and the last date each was searched.

Table 1: Databases searched and last date each was searched.

Database Searched	Last Searched
ASEE PEER Document Repository	January 2016
Compendex [Engineering Village]	January 2016
Education Resources Information Center (ERIC) [EBSCO]	January 2016
Inspec [Engineering Village]	January 2016
Library Literature and Information Science [EBSCO]	January 2016
Library and Information Science Abstracts (LISA) [ProQuest]	January 2016
Library, Information Science and Technology Abstracts (LITA) [EBSCO]	January 2016
Professional Development Collection [EBSCO]	January 2016
Scopus	January 2016

Database searching was performed by combining the concepts of IL, instruction, engineering, and undergraduate students. Table 2 displays the searches performed in two of the databases utilized, Compendex and ERIC.

Table 2: Search strategies performed in Compendex and ERIC.

Database	Search Strategy	Notes
EV Compendex - Search 1	Search constructed using the “Quick Search” option: Search Field 1: ("online searching" OR "information use" OR "information retrieval"); selected “Controlled term” AND Search Field 2: engineer; selected “Subject/Title/Abstract” AND Search Field 3: (teach OR instruct OR pedagogy); selected “Subject/Title/Abstract” AND Search Field 4: student; selected “Subject/Title/Abstract” This search results in the following output: ((((((("online searching" OR "information use" OR "information retrieval")) WN CV)) AND ((engineer) WN KY)) AND (((teach OR instruct OR pedagogy)) WN KY)) AND ((student) WN KY)), English only	Limits applied: English only, dates 2000-2016 left auto-stemming on Compendex does not contain a specific thesaurus term for “information literacy” so an additional search was performed to capture this specific terminology and its synonyms. 212 results received in January 2016 To replicate this search, at the time of publication, it is necessary to build the search using the “Quick Search” feature. The EV Compendex interface returns zero results when the “output” string is entered into the “Expert Search” box.
EV Compendex - Search 2	Search constructed using the “Quick Search” option: Search Field 1:("information literacy" OR "information needs" OR "information gathering" OR "library instruction" OR "bibliographic instruction" OR "information fluency") ; selected “Subject/Title/Abstract” AND Search Field 2: engineer; selected “Subject/Title/Abstract” AND	Limits applied: English only, dates 2000-2016 left auto-stemming on 146 results received in January 2016 To replicate this search, at the time of publication, it is necessary to build the search using the “Quick Search” feature. The EV Compendex interface returns zero results when

	Search Field 3: (teach OR instruct OR pedagogy); selected "Subject/Title/Abstract" AND Search Field 4: student; selected "Subject/Title/Abstract" This search results in the following output: (((((("information literacy" OR "information needs" OR "information gathering" OR "library instruction" OR "bibliographic instruction" OR "information fluency")) WN KY) AND ((engineer) WN KY)) AND (((teach OR instruct OR pedagogy)) WN KY)) AND ((student) WN KY)), English only	the "output" string is entered into the "Expert Search" box.
ERIC	(((DE "Information Literacy" OR DE "Information Needs" OR DE "Information Retrieval" OR DE "Information Management" OR DE "Information Seeking" OR DE "Search Strategies") AND (DE "Undergraduate Students" OR DE "College Students" OR DE "College Freshmen"))) AND (DE "Instruction" OR DE "College Instruction" OR DE "Library Instruction" OR DE "Instructional Improvement") AND engineer*	Limited applied: 2000-2015 (all results returned in English so an additional filter wasn't needed) "information literacy"; "information needs" are controlled terms; "information retrieval" is a broad term with lots underneath, may be gathering too much; "information utilization" another broad term, too broad, so skipped; "undergraduate students" is a controlled term No 2015 articles returned. 7 results received in January 2016

Screening, Eligibility, & Inclusion
The database search results were exported to Endnote Desktop. Endnote was used to identify and remove duplicate entries. The study selection for this review was achieved using two-levels of screening, an abstract level review and a full-text level review.

The authors used Endnote to perform the abstract level screening of results. Two of the four authors participated in the abstract level review. The eligibility criteria used consisted of the following:

- Contains a specific intervention focused on something related to IL

- Engineering undergraduate students are included in the study population
- Includes a clear (i.e. what the assessment instrument was, its timing) and full assessment of IL learning (not only measuring student engagement or opinion; needs a control group, comparison group, or pre-set target of effectiveness)
- The amount of IL assessment data reported is more than one question
- Timeframe: 2000-present
- English language

The articles remaining after the abstract level review was concluded were exported from Endnote and imported into Rayyan, a free software tool available to assist with performing SLRs. Article .pdf's were added to the Rayyan records for the full-text review. All four authors participated in the full-text level review. At least two authors reviewed each of the articles. In cases of discrepancies, all four authors evaluated and discussed the articles to come to a decision regarding inclusion or exclusion. Google Sheets was also utilized to assist with the full-text level review, due to a limitation of Rayyan not permitting notes to be added to records.

Data Collection from Included Studies

Using Google Sheets, data was extracted from studies that met the inclusion criteria. The details extracted consisted of the following elements:

- Method of intervention (e.g. face-to-face, online (if online, # of videos/modules and if they were interactive))
- Whether the work involved collaboration with disciplinary faculty
- Pedagogical technique (e.g. lecture, problem-based learning)
- IL topics covered (e.g. general, citation, patents, copyright, plagiarism)
- Engineering student population (e.g. first year, sophomore design, capstone)
- Type of course (e.g. mechanical engineering, civil engineering, mixed)
- Effectiveness of intervention (effective, ineffective, mixed, no difference)
- Artifact type (e.g. pre-post tests)

Results

Figure 1, a PRISMA flow chart [16], details the results of this SLR.

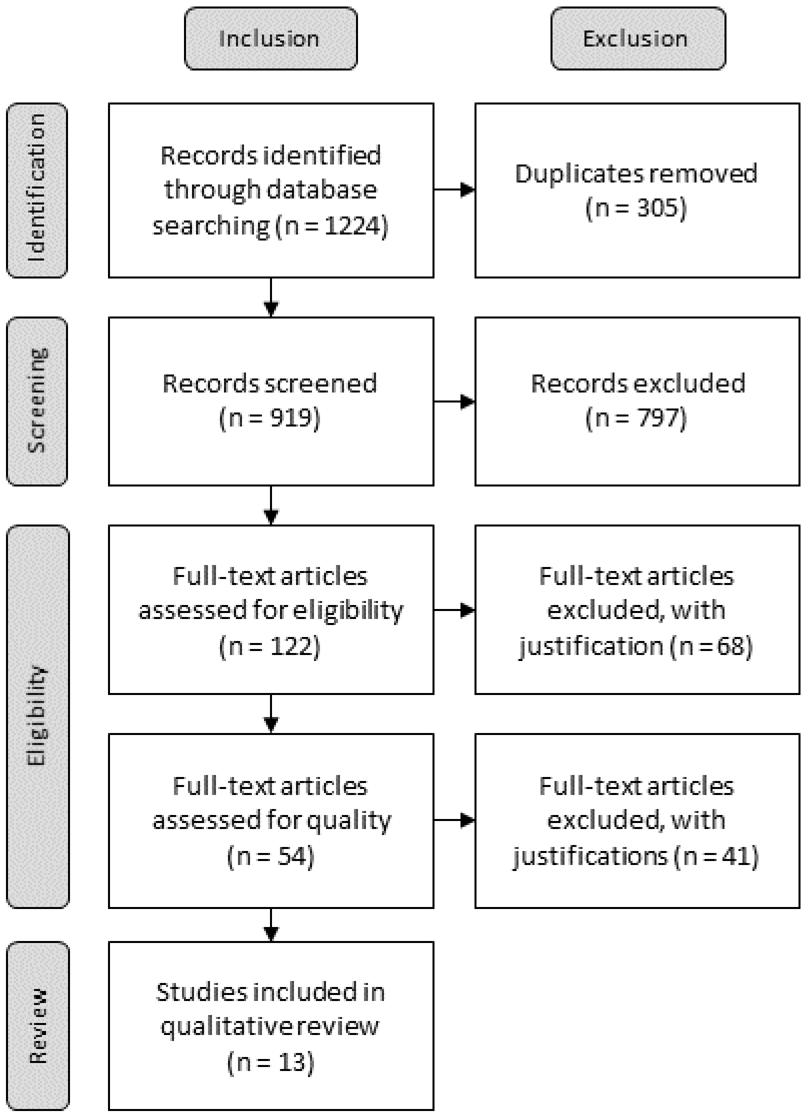

Figure 1: Flow chart describing the PRISMA process, with the number of studies included at each stage of this review

The initial searches generated 1224 results. 305 duplicates were removed prior to title/abstract screening. Two authors screened all of the remaining 919 items, eliminating those that were clearly outside the inclusion criteria established prior to searching, and keeping any that could not be accurately assessed with the limited information. The first screening resulting in removing an additional 797 records, leaving 122 that needed to have full-text retrieved for the second round of review. The review of the full-text articles lead to the exclusion of another 68 articles, leaving 54 articles to be assessed for the quality of the study. After calibration among the authors about how the term "effective" was used for this review, another 41 items were removed, leaving a final set of 13 articles. Appendix A provides a summary of these 13 studies.

Limitations - Risk of Bias Across Studies

Due to the parameters identified, varied database index/abstracting practices, and the reliance on article titles, abstracts, and author-supplied terms where controlled terms do not exist for "information literacy," there are inherent limitations to the results of this study. While the authors made extensive attempts to be comprehensive (which proved to be time consuming, as explained in the *Discussion* section), there were limitations with the keywords selected, as they may not be inclusive of all of the possible "information literacy" synonyms and related terms and phrases. Author-supplied abstracts and terms are also limiting because they may not be vetted across the controlled vocabulary of the field(s), thereby determining inclusion or exclusion in the search results. Lastly, only English language studies were included, potentially eliminating studies that would have met the inclusion criteria published in other languages.

Discussion

The authors learned several lessons through conducting an SLR. First, the searches constructed, combined with the large number of databases searched, generated a larger collection of records than expected. Upon initial screening of results, it became clear that the authors' attempt to be comprehensive, rather than balancing the precision of the search with the desire for comprehensivity, gathered a large portion of records unrelated to the topic of interest. For example, the inclusion of phrases, such as "information use" and "information retrieval" returned results more related to computer science and less about information literacy in some cases. These terms were selected because some databases (e.g. Compendex) do not contain a controlled term for "information literacy" and the authors desired to include not only librarian IL studies, but also IL interventions conducted by engineering faculty members that may be indexed and/or described with different terminologies. Similarly, the education databases allow for designating what level students are of interest, such as "undergraduate students" or "college students," which cannot be fully replicated in the engineering and LIS databases, where the more general term "students" was used. The translation of searches across subject areas is nuanced. There is an art to a well-crafted search string, and the authors could have saved themselves some time in reviewing records if the searches has been a bit more tightly defined. However, this would have run the risk of excluding studies not described or indexed using typical librarian terminologies.

As described in the *Methods* section, during the course of this review, several different tools were used for information gathering, data handling, and review. The initial results were all gathered into an EndNote database, which was stored on a shared server, where the authors could all access the EndNote library. This provided a robust mechanism for duplicate identification and removal and allowed for accurate tracking of the number of records at any point in the process. Several of the other citation management programs will do automatic duplicate removal upon loading results, which makes keeping track of a total number of records found and duplicates removed challenging, and reinforced the decision to use EndNote. The authors did not take extra steps to record initial screening decisions in a method that would be blind, which could have impacted the reviewer decisions. EndNote also enables fielded searching by criteria that allowed the authors to easily identify the places where there was agreement to remove a paper, and where the reviewers disagreed.

Prior to retrieving all of the full-text, the authors decided to move to the free SLR resource, Rayyan. This change was made to enable easier review of the full-text when working remotely, as one author was having difficulty with EndNote using a shared library in a remote location with any consistency. Rayyan can be used to highlight any keywords identified by the user, as well as record the reasons for particular decisions to mark a record for exclusion. The full-text screening decisions were also recorded in an unblinded fashion, due to functionality limitations of Rayyan. In this software, in "blinded" mode, it is not currently possible to use labels, or create unique groups, and then collate the results once the review setting is switched to unblinded. When merging unique groups, the software allows the last decision to take precedence. For this reason, the authors used the "unblinded" mode, which may have impacted the decisions of reviewers. In addition, Rayyan tended to get overwhelmed if more than one person in a review was making changes simultaneously, and when using labels, it will only let the user who added a label remove it later. Despite these limitations and glitches that happened due to the ongoing development of Rayyan, it did help four authors work together on this project and collate inclusion results.

While working through the full-text review, and again during the quality assessment for the papers in the study, the authors found themselves regularly having to review the inclusion criteria and get more explicit about exactly what was intended. The need for agreement led to discussions such as what counted as assessment, what is meant by effective, and how these items are represented in a particular study. The authors agreed not to accept a statement of effectiveness from the paper authors, rather the paper needed to include some measure of student learning gain, which could be done by pre/post measures, or some comparison between groups such as, qualitative measure with a rubric, or a quiz or graded assignment.

Conclusion and Future Work

There are several preliminary conclusions to be drawn, many of which will not be surprising to the engineering librarian community. The dataset came down to just 13 items because much of the EIL literature is based on student self-report data on how the class went, or was it enjoyable, rather than on actual student learning gains. As such, these papers did not meet the criteria for demonstrated learning gains as a measure of effectiveness. In addition, some papers were excluded for lack of clarity about methods. In these studies it is not evident how either the intervention and/or the assessment was conducted, with regard to timing, instrument used, etc. Some additional papers were excluded because a control or comparison group was not included to establish "effectiveness" of the intervention. An example of this type of exclusion is a citation analysis performed after an intervention with no baseline or other comparison. Overall, the authors note the EIL literature frequently reports descriptive statistics, showing that data has been gathered, but sometimes falls short of a full analysis that allows the researchers to draw meaningful/well-grounded conclusions from the data. The authors plan to complete a full analysis of the papers identified for inclusion and publish the results in a journal article.

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[6] M. J. White, "The history of the Engineering Libraries Division, part 1 - 1893 to 1960," in *2016 ASEE Annu. Conf. Expo.*, 2016. https://peer.asee.org/26170.

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[8] A. Brettle, "Information skills training: a systematic review of the literature," *Health Info. Libr. J.*, vol. 20, no. s1, pp. 3–9, Jun. 2003.

[9] R. J. Jacobs, J. Q. Lou, R. L. Ownby, and J. Caballero, "A systematic review of eHealth interventions to improve health literacy," *Health Informatics J.*, vol. 22, no. 2, pp. 81–98, Jun. 2016.

[10] A. M. Fiegen, "Systematic review of research methods: the case of business instruction," *Ref. Serv. Rev.*, vol. 38, no. 3, pp. 385–397, Aug. 2010.

[11] A. M. Fiegen, "Business information literacy: a synthesis for best practices," *J. Bus. Financ. Librariansh.*, vol. 16, no. 4, pp. 267–288, Oct. 2011.

[12] D. Koufogiannakis and N. Wiebe, "Effective methods for teaching information literacy skills to undergraduate students: a systematic review and meta-analysis," *Evid. Based Libr. Inf. Pract.*, vol. 1, no. 3, p. 3, Sep. 2006.

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Appendix A: Summary of the 13 Articles Meeting the Systematic Review Inclusion Criteria

Citation	**Results Effectiveness**	**Type(s) of Assessment**
[1] W. Baer, "Using videos to teach the ethical use of engineering information," in *2008 ASEE Annu. Conf. Expo.*, 2008. https://peer.asee.org/4197.	Effective	Pre/Post Tests
[2] A. Bradley, D. Latta, and M. Harkins, "Work in progress: Collaboration for quality: A librarian-faculty partnership to assess students' information literacy in freshman engineering," in *2013 ASEE Annu. Conf. Expo.*, 2013. https://peer.asee.org/22767.	Effective	Citation Analysis
[3] G. Hart and M. Davids, "Challenges for information literacy education at a university of technology," *Innovation*, vol. 41, no. 1, pp. 25–41, 2011. http://hdl.handle.net/10566/440.	Effective	Pre/Post Tests
[4] C. Hsieh and L. Knight, "Problem-based learning for engineering students: An evidence-based comparative study," *J. Acad. Librariansh.*, vol. 34, no. 1, pp. 25–30, 2008. https://doi.org/10.1016/j.acalib.2007.11.007.	Effective	Pre/Post Tests
[5] S. Kajiwara, L. Taber, and C. Mullen, "Engineering research web modules - Designing for students' needs," in *2002 ASEE Annu. Conf. Expo.*, 2002. https://peer.asee.org/11209.	Effective	Citation Analysis
[6] C. Leachman and J. W. Leachman, "If the engineering literature fits, use it! Student application of grey literature and engineering standards," in *2015 ASEE Annu. Conf. Expo.*, 2015.. https://doi.org/10.18260/p.24218.	Moderate to none	Citation Analysis
[7] G. E. Okudan and B. Osif, "Effect of guided research experience on product design performance: A pilot study," *J. Eng. Educ.*, vol. 94, no. 2, pp. 255–262, 2005.	Effective	Design Project Grades
[8] B. Otis and L. Whang, "Effect of library instruction on undergraduate electrical engineering design projects," in *2007 ASEE Annu. Conf. Expo.*, 2007. https://peer.asee.org/2620.	Effective	Citation Analysis
[9] M. Phillips, S. Lucchesi, J. Sams, and P. J. van Susante, "Using direct information literacy assessment to improve mechanical engineering student learning - A report on rubric analysis of student research assignments," in *2015 ASEE Annu. Conf. Expo.*, 2015. https://doi.org/10.18260/p.24999.	Effective	Assignment Analysis
[10] A. Van Epps and M. Sapp Nelson, "One or many? Assessing different delivery timing for information resources relevant to assignments during the semester. A work-in-	No difference	Citation Analysis

progress," in *2012 ASEE Annu. Conf. Expo.*, 2012. https://peer.asee.org/21756.		
[11] M. Tomeo, "Continuing library instruction via online tutorials," in *2009 ASEE Annu. Conf. Expo.*, 2009. https://peer.asee.org/5420.	Effective	Pre/Post Tests
[12] Y. Xu, L. Dong, and T. Nawalaniec, "Enhancing engineering students' knowledge of information literacy and ethics through an interactive online learning module," in *2010 ASEE Annu. Conf. Expo.*, 2010. https://peer.asee.org/15812.	Effective	Pre/Post Tests
[13] Q. Zhang, M. Goodman, and S. Xie, "Integrating library instruction into the course management system for a first-year engineering class: An evidence-based study measuring the effectiveness of blended learning on students' information literacy levels," *Coll. Res. Libr.*, vol. 76, no. 7, pp. 934–958, 2015.	Effective	Pre/Post Tests