

Who Listens to Whom? A Citations Analysis of Recent Papers on Engineering Design Education

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Abstract:

Design is a central component of engineering education and practice. Students may experience design as early as their freshman year, and most students conclude their baccalaureate education with a capstone design experience. In addition, there are many studies in engineering design that can be of value to design educators. In this paper we describe the methods, data, and results of a citation* analysis of journal and conference articles concerning design education. Our goal was to determine the extent to which design educators bring outside knowledge into the classroom or reference design research. The citation analysis was conducted by selecting articles with “design” in the title from selected engineering journals and conferences from the past five years. Bibliographic entries from each of the resulting 274 articles were entered into a database, and this information was imported into a spreadsheet to analyze the number and kinds of citations. For example, the information could be catalogued and sorted by type (e.g., journal, book, conference), specific sources (e.g., Journal of Engineering Education), and topics (e.g., book titles that contained “assessment”). From this research we discovered that most of the citations were publications by design educators, not design researchers. In particular, most of the journals, conferences, and periodicals were from the engineering design education community. In comparison, references to design research or education research sources, such as AERA and Research in Engineering Design, were rare. We are currently using this research to develop a workshop for introducing design educators to design research and illustrating how design research may be used in the classroom. This research may also be used to develop an awareness of communication patterns within the design education community, describe the current state of design education, and identify areas of improvement in design education.

*The words “citation” and “reference” are used interchangeably throughout the document.

Introduction:

Engineering design education is vital to the successful instruction of future engineers. It has recently become apparent that graduates are deficient in vital areas of design, thus affecting the engineering industry as a whole. At the Center for Engineering Learning and Teaching (CELT) we know that research exists that could be of value to educators. We have envisioned a workshop that would bring educators and researchers together where educators’ questions about effective design teaching could be answered and researchers’ findings could be utilized. To effectively design this workshop, it was necessary to determine what engineering design

educators are doing and whom they are listening to when they make decisions about their teaching. This paper explores what kinds of sources authors reference when discussing engineering design education. More specifically, we sought to address the following questions:

- How frequently are engineering design educators referring to works relevant to their field?
- How are these educators using this information to improve their teaching?
- To what extent are different engineering design communities (educators, researchers, etc.) communicating?
- How can these findings be utilized to improve engineering design education?

Our method was to conduct a citations analysis of bibliographical references in selected papers by design educators. We used this method to (1) catalog the references cited by engineering educators in their papers and (2) discover the extent to which engineering faculty are referring to other people's research when describing their own teaching. The results from this study were utilized to design a workshop to bring educators and researchers together.

In this paper, we report the results of our citations analysis. This includes a description of our method for exploring what sources people are referencing when writing about engineering design education, a summary of our findings, and implications for design education.

Background

We believe engineering research should inform the engineering design education community. Other educational communities (such as science education) effectively utilize research in their teaching practices (e.g., McDermott & Redish, 1999; McDermott, 1997; Hunt & Minstrell, 1994). As illustrated by the large number of papers disseminated through such avenues as journal papers and conference proceedings (e.g., ASEE, FIE, JEE), many design educators are actively talking about what they do in the classroom. This suggests that many have gone beyond merely teaching the materials and are striving to teach so as to best prepare their students.

Fortunately, there is plenty of research available to support design educators in this aspiration. Design research can offer frameworks for characterizing design (e.g. decision-based design), understanding the difficulties students experience when they design, and understanding the wide variety of strategies expert designers use (e.g. verbal protocol analysis, ethnographies). Each of these has the potential to contribute to the teaching and learning of design. The question is whether design educators are referencing this large body of research.

One way we can rigorously determine the extent to which design educators talk or listen to design researchers is through citation analysis in which we explore who they reference in their publications on design education. Authors use citations to reference another person's or group's ideas or research while developing their understanding. For example, an author may choose to cite another source to justify a motivation for their activities, locate themselves with respect to an idea, or support or validate their efforts. Similarly, authors may cite another source to articulate what they are doing (such as definitions or models) or help others locate related work.

Citation analyses are often used to gain a quick insight into a paper or groups of papers. Citation analysis has been used in many diverse fields, such as computer science (Giles, 2001), business computing (Tanner, 1993), and school psychology (Frisby, 1998). One of the first studies was conducted in 1964 in creating the *Science Citation Index* (Garfield, 1972). This database catalogued journals and their citations and was used to rank journals by frequency and impact of citations for science policy studies (Garfield, 1972). By 1971, the database included over 27 million references. Citations analysis is a very flexible analysis tool. As Tanner notes (1993, pg. 233), “there is no one ‘accepted’ means of conducting a citation analysis study.” Citations analyses can be molded by the researcher to yield a variety of results. In the past, this method has been used to rank sources by the number of publications that reference them (Garfield, 1972; Summers, 1984; Tanner, 1993; Frisby, 1998), compare different forms of publications (Giles, 2001), and determine the number of self-citations (Frisby, 1998), along with many other objectives.

Method

Our method was to conduct a citation analysis of bibliographical references of papers on engineering design education. Papers were selected by surveying *engineering education* journals and proceedings of major engineering education conferences from the past five years and selecting papers with “*design*” in the title. Because we were interested primarily in the teaching of engineering design, we did not include journals or conferences that are predominantly research (e.g. Design Studies, ICED, etc.). Overall, we identified 274 papers for our study. The list of journals that we selected from is included in Table 1.

Table 1. Sources for Literature on Engineering Design Education

Source	Source Type	Dates	# (2828 total)
Journal of Engineering Education (JEE)	Journal	1995-2001	16
IEEE Transactions on Engineering Education (IEEE)	Journal	1995-2001	13
International Journal of Engineering Education (IJEE)	Journal	1994-2001	46
Australasian Journal of Engineering Education	Journal	1995-2001	1
SEFI European Journal of Engineering Education	Journal	1996-2001	4
Global Journal of Engineering Education	Journal	1997-2001	1
International Journal of Mechanical Engineering Education	Journal	1996-2001	13
Journal of Professional Issues in Engineering, Education and Practice	Journal	1999-2001	2
International Journal of Electrical Engineering Education	Journal	1996-2001	5
Proceedings of the ASEE Annual Conference	Conference	1995-2001	32
Chemical Engineering Education (CEE)	Journal	1995-2001	21
Proceedings of the Frontiers in Education Conference (FIE)	Conference	1996-2001	120

For each of the 274 papers selected, we carefully counted and categorized each of the citations. Our framework for analyzing the citations was based on the following measures: the number of citations, the types of citations by source, and the community associated with the source. The number of citations was calculated by counting the total number of citations per paper as well as the number of citations by individual source. The types of sources were categorized into journal articles, conference proceedings, books, magazines, curricular materials, websites, and reports. Kinds of sources that were not easily categorized or were extremely diverse were simply labeled “other”. Categorizing the citations by source provides some insight into the credibility or worth

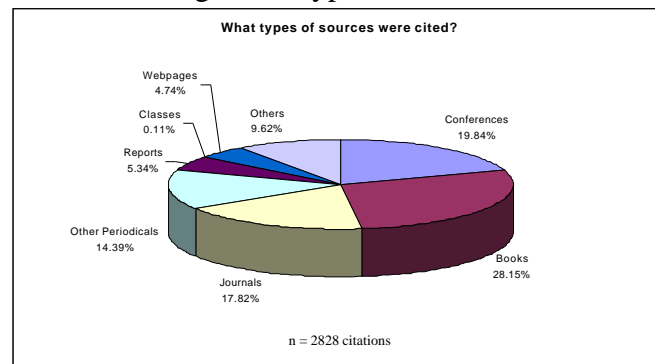
of the referenced material. For example, peer-reviewed articles and national reports tend to have more credibility than sources that are examined by few, if any, external reviewers.

For journals, conferences, books and reports we pursued a second level of analysis to gain some insight into the communities with whom the author associates. Communities may be described broadly, such as engineering education, or more discipline specific such as Mechanical Engineering, software design, or design research. Similarly, these communities may reveal the kinds of ideas or information the author is bringing to inform their work or share with others. For journals, the types of communities included journals that publish broad accounts of engineering education (e.g., JEE, IJEE, IEEE) and those that tend to publish design research (e.g., Design Studies, Research in Engineering Design). For conferences, communities included engineering education conferences (e.g., ASEE, FIE), education research conferences (e.g., AERA), and design research conferences (e.g., ICED). Categories for books included books with “design”, “assessment”, “evaluation”, “teaching”, or “learning” in the titles. Finally, categories for reports were based on who produced the report such as the NSF, NRC, or ABET.

Results

As Figure 1 shows, there was a wide variety of sources that authors cited. These range from journals and conferences to web pages and course syllabi. As can be seen in Figure 1, conferences, books, journals, and other periodicals were referenced more often than the other sources.

Figure 1: Types of Sources



We also counted the number of citations authors were making in total and in certain categories. In the 274 papers, there were a total of 2,828 citations. The papers had an average of approximately ten citations each, including an average of two conference and two journal citations each. Figure 2 shows the distribution of the number of total citations that were made. Figures 3 and 4 show the distribution of conference and journal citations, respectively. These latter graphs show an exponential curve in their distributions.

In order to get a more detailed picture of which sources authors were citing most frequently, we recorded the specific source of each citation from the Conferences, Books, Journals, Other Periodicals, and Reports categories. For example, in the Conference category, we specified which conference it came from; whether it was ASEE, FIE, AERA, ICED, an international conference or some other conference. We did not do this for the Classes, Websites, and Other

categories because many of these sources are not amenable to a citations analysis and are probably widely varied. These subcategories, and the percentage of citations referring to them, are shown in Figures 5 through 9. A summary of results is provided below for types of journals, conferences, books, periodicals, and reports.

Figure 2: Number of Citations

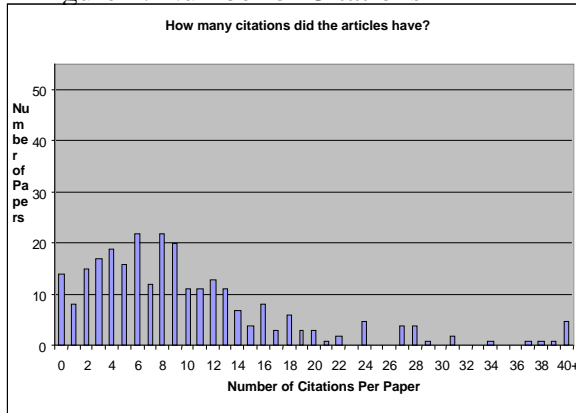


Figure 3: Number of Conference Citations

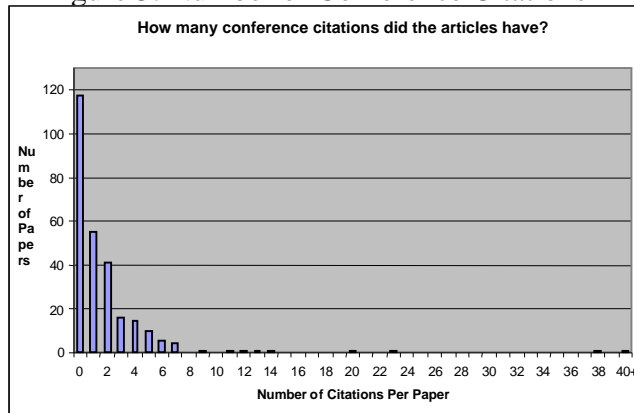
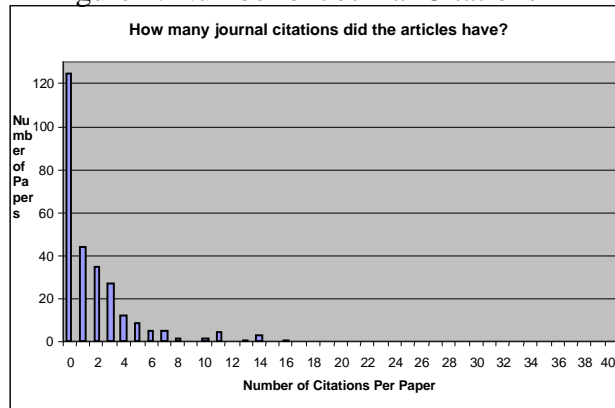


Figure 4: Number of Journal Citations



Journals:

Figure 5 shows the numerous journals cited by design educators. Of the 504 references to journal articles, 41% were from JEE (a.k.a. EE) and 15% were from IEEE. The IJEE and CEE also made up small portions of these citations. The Others subcategory contains miscellaneous journals from many disciplines, such as the Journal of Glaciology. As illustrated in Figure 5, only 5% of the journal citations came from widely recognized journals on design research (eg., Design Studies, Design Theory & Methodology, and Research in Engineering Design).

Conferences:

Of the 561 references to conferences, a large majority (approximately 62%) were either from ASEE or FIE annual conferences (Figure 6). Less than 1% were references to AERA or other education research conferences (.18%). The Other subcategory consisted of discipline specific and small specialized conferences, such as the Conference of the National Collegiate Inventors

and Innovators Alliance.

Figure 5: Journals Cited

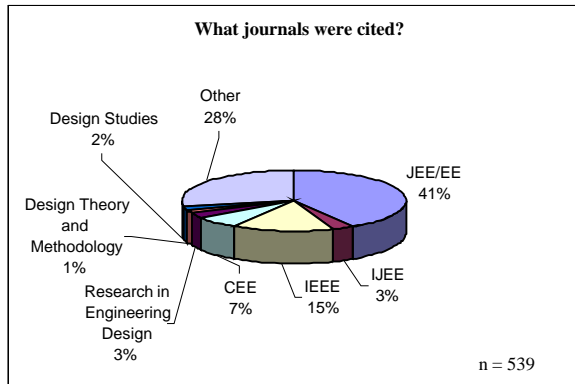


Figure 6: Conferences Cited

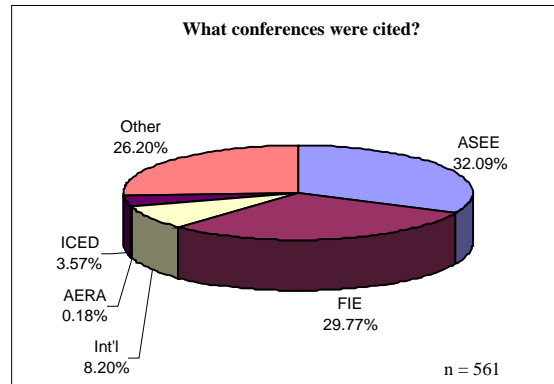


Figure 7: Books Cited

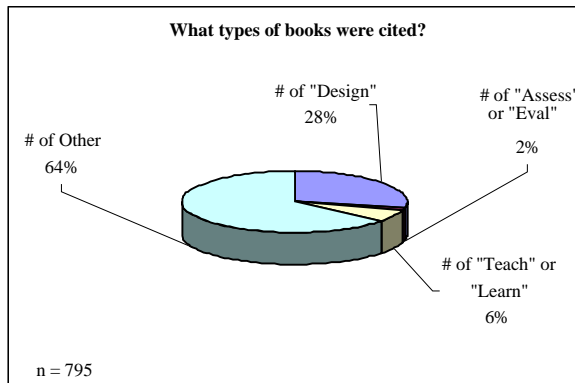


Figure 8: Periodicals Cited

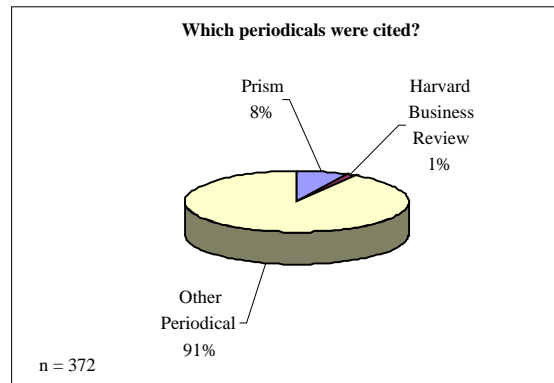
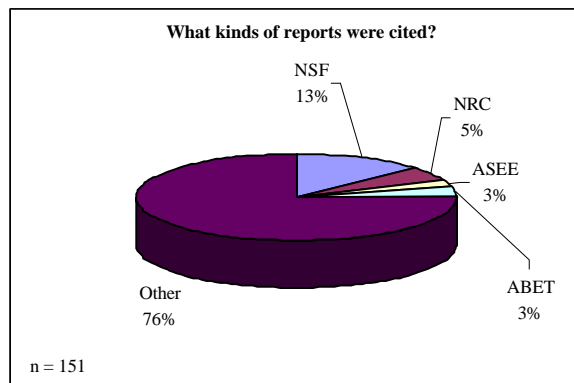


Figure 9: Reports Cited



Books:

Figure 7 shows the types of books authors tended to cite. Of the 795 books that were referenced, 28% contained the word “Design” or some variation within the title. “Teach,” “Learn” or some variation of these words were in the titles of approximately 6% of the book citations, and 2% contained “Assess,” “Evaluate” or some variation within the title. A few of the more common books cited include Engineering Design, Designing Engineers, and Total Design. However, more than three quarters of the books cited were not easily categorized or were extremely diverse. These books include titles such as VHDL Made Easy, Separation Processes, and

Technical Report Writing.

Periodicals and Reports:

The periodicals and reports were more difficult to separate into separate categories due to the wide variety of sources. The main sources for periodicals were Prism and the Harvard Business Review (Figure 8). As Figure 9 shows, the main sources for reports were the National Science Foundation (NSF), the National Research Council (NRC), the Accreditation Board for Engineering and Technology (ABET), and the American Society for Engineering Education (ASEE). The Other subcategory contained any other source that was listed as a report, such as internal technical or committee reports.

Discussion

In this process we have looked at the number of citations authors make and the types of sources that are cited in recent articles on engineering design education. The results give us a sense of who design educators are listening to and what information design educators are bringing to their teaching.

One observation we have made during this research is that design educators are communicating well within their own community, but not as well with other communities, such as the education and design research communities. This is evident from the abundance of citations relating to the journals or conferences of ASEE (such as JEE, ASEE, FIE and Prism) and the limited number of citations to research journals or conferences (such as AERA and Design Studies). We also found that authors are more likely to reference conferences than journals, and that conferences are effective places for the dissemination of ideas and undertakings. Of those who cite books, few are predominantly about teaching, learning or assessment issues (few have those words in the title). Only 8% of the books cited had the words teach, learn, assess, evaluate, or some variation of these within the title. Approximately one fourth of those who cite books cite books predominantly about design.

We have also seen that design educators are not referencing broad studies of engineering education or engineering education policies. They are more focused on or motivated by their own specific aspect of engineering design, such as circuit design. This is evident through the limited use of reports from groups such as the NSF, NRC, and ABET. Reports from these groups tend to focus on identifying and articulating future needs for engineering education.

From this analysis, we can infer that the average design educator is not consistently drawing from a wide variety of sources. The average paper has about ten citations, most of these being from similar sources (e.g., someone who cites books usually cites multiple books). This suggests that authors may not be drawing from multiple perspectives.

Concluding Remarks

By conducting this research, we have revealed several illuminating trends. Engineering design educators who are motivated enough to write a paper do not appear to be drawing from a broader perspective. Their papers tend to have few citations, and those citations do not include references

from a broader community, such as education and design researchers or reports on engineering education policy. One interpretation is that although design educators are actively striving to improve their courses and interact with their community, they may not be approaching their design teaching broadly.

Our results suggest that engineering design educators reference other educators, through conferences and education journals, but do not regularly reference engineering design researchers, which could be done through research journals or conferences. We know that educators write papers and articles, as do researchers, but it seemed that engineering design educators did not regularly reference engineering design researchers' work.

There may be more reasons for this; design and education research may not be accessible or seem relevant, or it may be difficult for educators to find the time to explore design research and identify appropriate or effective pathways between their practices and the available research.

To meet such challenges, we are currently designing a workshop to provide design educators opportunities to link design research more directly with how they teach engineering design. In other words, we want to support design teaching by making research findings accessible and practical. Our workshop will bring design educators and researchers together to discuss ideas and issues. This report shows that such groups generally do not have much contact with one another. We believe that in bringing these groups together, the entire engineering design community will benefit.

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