What a Systematic Literature Review Tells Us About Transportation Engineering Education

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What a Systematic Literature Review Tells Us About Transportation Engineering Education (and Why Other Engineering Disciplines Should Do One Too)

ABSTRACT

Engineering education research has evolved considerably over the last several decades and has revealed much about effective teaching practices for engineering. There is some concern that the level of adoption of these effective teaching practices across the engineering programs is relatively low and that meaningful assessment of student learning using innovative practices is rare. One reason for this may be a lack of meaningful dialogue about these practices at a discipline specific level, creating a disconnect between engineering education researchers and the larger group of education practitioners. A systematic literature review is a method for exploring a large amount of published material to expose underlying trends. This paper uses the sub-discipline of Transportation Engineering to illustrate the use of a systematic literature review as a catalyst for improving the dialogue on the adoption of more effective teaching practices and the assessment of student learning using these practices. This paper discusses the methodology for performing a systematic literature review, highlights some of the case study findings in the context of how these findings can be used to identify next steps for instigating transformative change in the field of transportation engineering education, and makes a case for the use of systematic literature reviews in other areas of engineering.

INTRODUCTION

A recent article in *The Journal of Engineering Education* by Borrego et al.[1] argues for the use of systematic literature reviews in engineering education. These types of reviews are used in other disciplines to summarize previous research in order to influence future practice. It has been suggested that the volume of previous research creates a barrier to those wishing to access the findings and recommendations, and that a systematic literature review can lower this barrier. Better accessibility to the findings of previous research can lead to a more informed identification of future research and to recommendations regarding current practice.

The term "systematic review" was defined by Borrego et al.[1] as a synthesis of existing work to answer particular research questions that were formulated by an interdisciplinary team. Systematic reviews are thorough in their search for previous work, as opposed to a review that looks for research that supports a particular point of view, and they follow an implicitly defined methodology.

Borrego et al.[1] conducted a systematic literature review of existing systematic reviews with the goals of identifying needs for future reviews in engineering education and recommending a methodology for performing the reviews that are appropriate to the discipline. From this work, they suggest the following primary purposes for conducting a systematic literature review in engineering education:

- trace the historical development of a discipline,
- describe the state of knowledge or practice on a topic,

- evaluate or develop theory, and
- identify opportunities for future research or innovations.

The 2011 book *Shaping Our World: Engineering Education for the 21st Century*[2], makes a compelling argument for a major restructuring of how engineering is taught. The challenge becomes how engineering educators should change both *what* they teach and *how* they teach. Most engineering faculty serve dual roles of teaching and conducting research, and most engineering faculty research is in technical fields rather than in engineering education. This can create a gap between engineering education researchers and the majority of faculty engaged in teaching engineering. There is a strong need to bridge this gap, and systematic literature reviews could be a powerful tool for doing so.

Transportation engineering education is similar to most fields in engineering in that there is a significant disconnect between what engineering education researchers have identified as best practices and what educators are implementing in their classrooms. We applied the methodology outlined in the Borrego et al.[1] article to the field of transportation engineering to determine what has been published about the sub-discipline with respect to engineering education. For this paper, transportation engineering is used as a case study to illustrate the methodology proposed by Borrego et al. and to provide examples of the types of insight that a systematic literature review can provide. The complete results of the systematic literature review can be found in a separate paper[3]. This paper describes the process of performing a systematic literature review, summarizes the results of the review in transportation engineering education, and discusses how other disciplines could benefit from such an approach.

PERFORMING A SYSTEMATIC LITERATURE REVIEW

The following sections summarize the methodology provided in Borrego et al. and use the recently completed systematic literature review in transportation engineering as a case study to show how the methodology can be applied[1,3].

Initiating the Review

The first step in performing a systematic review of the literature is deciding that such a study is needed. The previous section provided some reasons why a systematic review may be warranted, such as to document the historical development of a teaching method or to identify future research needs. Another key component to making this decision is to determine that a systematic review has not recently been done in the area of interest. Borrego et al.[1] found that very few systematic reviews have been done in engineering education, so it is likely that there is a need in most areas. However, researchers should confirm the need before beginning a new review.

Defining Scope and Formulating Research Questions

The next step in the review is to identify the scope and the research questions the systematic review will address. If the research question is too general, the literature review can become unwieldy and the results too broad to be of use. Borrego et al.[1] provide examples of how research questions can be formulated to be more specific; for example, they suggest rephrasing questions such as “What is known about X?” to “Is X effective under particular conditions?” or “What

factors influence the effectiveness of X?", where X could be a particular teaching practice such as the use of computer simulations to illustrate a theory.

For the transportation engineering education case study, we limited the scope to higher education, excluding sources dealing with professional development or continuing education, K-12 recruitment, and workforce pipeline issues. We initially hypothesized that the sub-discipline and higher education scope was specific enough that the research question could be quite broad. A preliminary review of the over 90 articles found showed that there were several primary topical areas in which the papers could be grouped. As a result, we believe that the goal of providing a useful resource for transportation engineering instructors and researchers in the field is better served by refining the original research question and conducting two reviews, each of which can be synthesized in a self-contained article. The single initial research question was revised into the following three questions[3]:

1. What instructional practices have transportation engineering educators employed to improve student learning at the undergraduate and graduate levels?
2. What techniques have been used to measure student learning in transportation engineering education?
3. How have transportation engineering curricula changed over time?
    a. Where does transportation engineering fit within engineering programs?
    b. How does transportation engineering fit within civil engineering programs?
    c. What topics are addressed within transportation engineering courses?
    d. How does transportation engineering preparation meet stakeholder needs?

Revisiting the research questions after an initial scan of the literature was found to be a useful approach given the objective of comprehensively documenting the sub-discipline of transportation engineering at the undergraduate and graduate level. The articles found in the literature search addressing research questions #1 and #2 above are discussed in the recent Transportation Research Record paper mentioned previously[3]; a second paper addressing curricular issues (question #3 and its sub-questions) is in progress.

Defining Inclusion Criteria

Three types of inclusion criteria were identified by Borrego et al.[1]:

1. Databases to be searched,
2. Combination of search words and logical connectors (AND, OR, etc.), and
3. Addressing the research question(s).

Borrego et al. provide a list of databases used for their systematic literature review; this is useful for broad reviews since their effort covered fields such as general education and psychology.

For the transportation engineering education case study, the selection of databases was determined first by the desire to limit results to the sub-discipline and second to focus on peer-reviewed sources. Transportation and engineering education resources were the primary focus. The citation lists of the papers that were identified initially formed another important resource. Use of citations can be helpful when literature addressing the research question is scarce. The process described above resulted in the archive list shown in Table 1 for the transportation engineering education case study[3].

TABLE 1: Archives and Search Terms Used (as in Hurwitz et al.[3])

Archives Searched (URL)	Search Terms Used
• ASCE Journal of Professional Issues in Engineering Education and Practice (http://ascelibrary.org/journal/jpepe3) • ASEE Annual Conference Proceedings (http://www.asee.org/search/proceedings) • European Journal of Engineering Education (http://www.tandfonline.com/toc/ceee20/current#.VBqT7fldWSo) • Google Scholar (http://scholar.google.com) • Web of Science (Thomson Reuters) (http://wokinfo.com/) • International Journal of Engineering Education (http://www.ijee.ie/) • ITE Journal & Annual Meetings (http://www.ite.org/library/) • Journal of Engineering Education (http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2168-9830) • Article Reference Lists • Transportation Research Information Database (TRID) (http://trid.trb.org/) • Frontiers in Education Conference Proceedings (http://erm.asee.org/frontiers.html)	• Education • Instruction • Instructional Practices • Traffic • Transport • Transportation Curriculum • Transportation • Transportation Education • Transportation Engineering Curriculum • Transportation Engineering Education Curriculum

The second inclusion criterion is the choice of search words and associated logical connectors. The search terms used highly impact the results and must be considered carefully. Some databases provide guidance on keyword selection. The keywords used should be directly related to the research question(s): if the keyword search is too broad, the analysis will be more difficult; if it is too narrow, the usefulness of the final review is diminished.

The final keyword search terms used in the transportation engineering education literature review are shown in Table 1. Any search terms shown with multiple words used AND logical connectors; no OR logical connectors were used. The term transport was not included initially and is a good example of how terminology can be regionally dependent. In transportation, the term “transport” is used mainly in Europe, and the addition of this term yielded some useful resources published outside of the United States.

The final inclusion criterion relates to whether the identified source addresses the specific research question. This requires a preliminary review of identified sources, often beyond reading just the source’s abstract since there can be a considerable disconnect between the abstract and the paper’s actual content.

For the transportation engineering education case study, we limited the scope to higher education. All papers addressing exclusively K-12 outreach, workforce recruitment, or workforce training were excluded. Several of the articles addressing higher education required further review and discussion. For example, were non-classroom based efforts (such as co-curricular or “bootcamp”-type experiences) relevant? Should we include papers that presented no

evidence of assessment of student learning? Discussion among the four authors was critical in making these determinations.

RESULTS

This section discusses the results in terms of the answers to the research questions as well as the process itself.

Results from the Systematic Literature Review in Transportation Engineering Education

Hurwitz et al.[3] describes in detail the literature reviewed in response to the research questions related to instructional practices and measurement of student learning. Forty-six papers met the inclusion criteria for these research questions.

The literature describing instructional practices was further divided into articles related to simulation, visualization, experienced-based and problem-based learning, and other types of active learning. The literature reported not only on the variety of active-learning approaches that have been employed, but also on the motivation of the instructor(s) for changing instructional practices. Most of these efforts are described in sufficient detail in the original articles such that another instructor should be able to implement the technique. A number of the efforts were supported through National Science Foundation or University Transportation Center grants. However, there was little evidence of adoption beyond the original instructor or team of instructors. The variety of work is encouraging, but no list of "best practices" emerged from the work reviewed. Thus, there remains a need for work that promotes adoption of effective innovative practices.

In the literature reviewed, student learning was measured through surveys, in-person interviews, direct assessment of student work, and concept maps; measurement of learning was not reported in all articles reviewed. Indirect measures, such as qualitative surveys of student opinion, were more common than direct measures, such as performance on an exam question. The most persuasive assessments of student learning employed mixed-methods approaches, combining a variety of qualitative and quantitative techniques. These findings reveal the need for more rigorous and quantified methods of student learning to be used in evaluating new and innovative approaches to teaching.

Lessons Learned from the Process

Conducting the systematic literature review enabled us to quantify the work related to transportation engineering education that has been published over time. The resulting graph shows an increasing trend, indicating that interest in such work has heightened over time, particularly in recent years (Figure 1). Much of the work has appeared since 2009, when the first Transportation Engineering Educators Conference was held[4]. This was the start of a concerted effort to build a community of transportation engineering educators; this cause was further pursued in a 2012 workshop funded by the National Science Foundation[5].

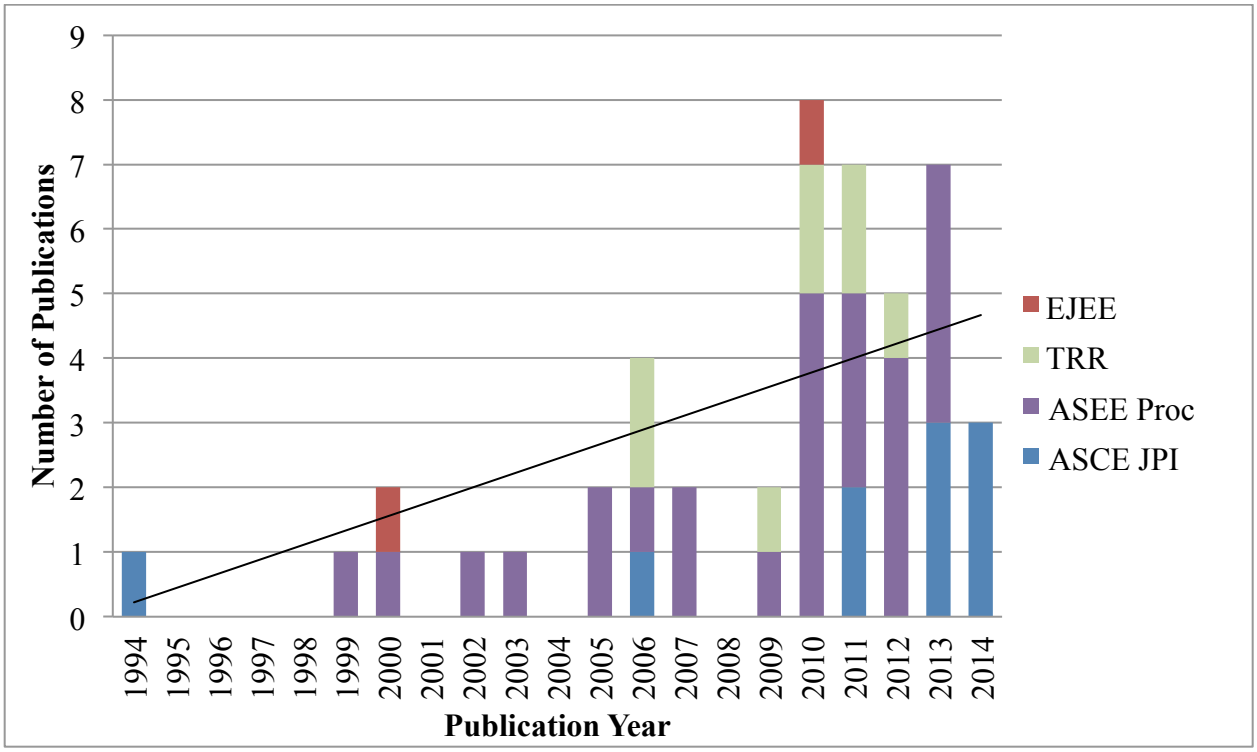

FIGURE 1: Frequency of Refereed Journal and Conference Publications by Year (as in Hurwitz et al.[3])

Borrego et al.[1] presented their model for a systematic literature review as a linear process. However, in gathering the articles based on the criteria we defined, we found it helpful to refine our questions, particularly in terms of subdividing those that had initially been rather broad into more targeted queries. We initially feared that enough literature did not exist to support meaningful results from more targeted questions; however, this turned out to be unfounded.

As mentioned previously, there was no list of best practices that emerged either in the transportation engineering education literature on instructional techniques or on measurement of student learning. This absence of definitive results and/or consensus within the profession is a finding in itself, suggesting that work in the area remains to be done.

CONCLUSIONS

Systematic literature reviews reveal the current state of a topic, consolidating research results in a way that makes them easily accessible to practitioners and identifying gaps in the existing body of knowledge. They also provide a way of quantifying the level of research activity over time in an area; the trends can show interest waxing and waning. For example, the transportation engineering education case study showed that research activity has been increasing, but that these efforts seldom build on one another.

Given the sparseness of systematic reviews in engineering education and the benefits identified in theory and practice, the time seems right for such reviews to be conducted in other engineering disciplines. More of this type of work has the potential to create the bridge between

educators in the classroom and engineering education research. Further, completion of systematic literature reviews in multiple engineering disciplines could yield interesting findings when the results are compared across disciplines.

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