A SNAPSHOT METHODOLOGICAL REVIEW OF JOURNAL ARTICLES IN ENGINEERING EDUCATION RESEARCH

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Abstract – Explicit discussion of methodology is important to better understand how knowledge claims are made in a field. In light of a methodological taxonomy, this exploratory review paper examined the research topics and methodologies that were used in a sample of 142 articles published in 2018 by four major engineering education journals. The analysis reveals that engineering education research exhibits varied profiles in different engineering education journals. It also identifies several patterns and trends in the current state of engineering education research. The findings will not only provide novice engineering education researchers with a snapshot, yet an illustrating view, of the emerging field of EER but also offer a starting point to examine critical questions in the field of EER, such as quality and rigor.

Keywords: engineering education research, quality, rigour, knowledge

1. INTRODUCTION

A number of review papers have been written to map and characterize engineering education research (EER) in the past two decades. Some of these reviews attempted to identify trends [1, 2]; and others focused on papers in particular journals [3, 4] or on specific research areas [5, 6]. These reviews demonstrate a keen interest among engineering educators and researchers in defining the emerging field of EER. These ongoing efforts also suggest that gaps in the knowledge about EER as a field still exist and need to be filled.

This paper is distinct from the previous review attempts in two ways. It aims to focus on methodologies used in EER papers, rather than their findings. Explicit discussion of methodology is important to better understand how knowledge claims are made in a field and reveal what methodologies have been typically used or what are emerging methodologies for knowledge production [7]. In addition, this review paper targets at the most recently published articles in four EER journals that appear to have a distinctive geographic orientation in terms of authorship. These journals are the Australasian Journal of Engineering Education (with an authorship mostly based in Australia and Asia), the European Journal of Engineering Education (with an authorship mostly based in Europe), the Journal of Engineering Education (with an authorship mostly based in North America), and the International Journal of Engineering Education (with no authorship concentration on particular regions). The purpose of the review is to examine the current state of EER regarding types of research, approaches used as well as topics addressed. This knowledge will not only provide novice engineering education researchers with a snapshot, yet an illustrating view, of the emerging field of EER but also offer a starting point to examine the field with a critical lens.

For that purpose, I coded a total of 142 articles published in 2018 by the four journals on the basis of a methodological taxonomy [8]. In what follows, I will first report the review methods, and then outline the findings from examining these articles in each of the four journals in terms of five dimensions: research topics, the nature of the paper, explanatory framework, data source, and data analysis. I will further discuss the trends and patterns identified from the findings and the implications to practical and epistemological understandings of the EER field. This exploratory methodological review was not conducted under a particular conceptual or theoretical framework, with the intention to leave the findings open to explanation in any conceivable ways.

2. REVIEW METHODS

This review intentionally focused on four major peer-reviewed journals: the Australasian Journal of Engineering Education (AJEE), the European Journal of Engineering Education (EJEE), the Journal of Engineering Education (JEE), and the International Journal of Engineering Education (IJE). The AJEE, EJEE and JEE are published respectively under the auspices of three region-based engineering education associations (The Australasian Association for Engineering Education, the European Society for Engineering Education, and the American Society for Engineering Education respectively); therefore their authors are most likely to be affiliated with these associations with specific geographic orientations although they all position themselves as “international” journals. This geographic orientation is also exhibited in the dominance of the editors and
members of their editorial boards from the regions where their respective engineering education associations are located. IJEE is different from the other three journals in that it is not sponsored by any engineering education association but is managed by an engineering school of an Indonesian university; and the member composition of its editorial board is mixed in terms of regional affiliation.

For the purpose of this paper, I reviewed the areas of research and the methodologies used in a total of 142 articles, which consisted of all the articles published in 2018 in the AJEE (10 articles), EJEE (64 articles), and JEE (24 articles), and two of the six issues of the IJEE (48 articles in Issues 1 and 4). The scope of these four journals as stated on their websites and the typical number of publications per year are presented in Table 1. Arguably, the papers published in these journals constitute a sample of all journal articles published in the field of EER.¹ Due to the different geographic authorship orientations of these journals, their published articles may have captured perspectives across the world about various approaches to conducting EER. I did not include conference proceedings into this review due to a larger variation among conference papers with respect to quality than journal articles.

The comparison of the scope statements of these journals shows two features by which they qualify EER: scholarship/scholarliness versus practice/usefulness. The scholarliness-vs-usefulness divide is made explicit in the aims and scope of EJEE [9]:

- Usefulness implies that papers should be useful to readers outside the context where the work was made. Usefulness can take many forms, to readers who can be educators, researchers, specialists, leaders, or other stakeholders of engineering education.

- Scholarliness refers to the significance and novelty of the contribution, consistency and soundness of the research approach, connection to relevant literature, coherence and readability of the paper, as well as credibility and quality of the ideas and insights generated.

| Table 1. Characteristics of four journals being reviewed |
|----------------|----------------|----------------|----------------|
| Journal title | Scope statements | Number of Issues per year | Typical number of articles per issue |
| AJEE | “It is the policy of the AJEE to publish a variety of contributions on the scholarship and practice of engineering education”³ | 2 | 4 |
| EJEE | “It is a European journal with global readership and authorship…. It invites relevant contributions that combine scholarliness with usefulness for improving engineering education.”⁴ | 6 | 12 |
| IJEE | “It has been serving as an international archival forum of scholarly research related to engineering education for over thirty years.”⁵ | 6 | 24 |
| JEE | “The Journal of Engineering Education serves to cultivate, disseminate, and archive scholarly research in engineering education.”⁶ | 4 | 6 |

I coded the 142 articles in five dimensions: research topic, nature of the paper, explanatory framework, data source, including the scope of data collection, and data analysis methods. These dimensions were drawn upon the methodological taxonomy developed by Malmi and his colleagues [8, 10] to classify EER articles. In addition, I used the main EER areas identified by Borrego and Bernhard [11]— instructional or curriculum development, student learning and its assessment, retention and diversity of engineering students— as the starting point to categorize the topics of interest.

In the methodological taxonomy [8], specific descriptors are used to qualify each of the dimensions. The nature dimension presents the general character of the paper, which can be one of four categories: empirical papers report results from data collection and analysis to address specific research questions; case reports describe an educational intervention, such as a new instructional or assessment method or a new

¹ A list of other journals that publish EER articles can be found at http://terg.cett.hku.hk/wp-content/uploads/2017/03/e3r-inserts-list.pdf
² https://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=ceee20
³ https://www.tandfonline.com/action/journalInformation?show=aimsScope&journalCode=ceee20
⁴ https://www.ijee.ie/Aims_and_scope_2015.html
⁵ http://www.asee.org/papers-and-publications/publications/jee

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learning resource or tool, in a specific educational setting, sometimes being accompanied with an evaluation study; *theoretical papers* discuss theoretical aspects of engineering education; and *position papers or proposals* present a position or a novel idea, technology, or resource that has not yet been implemented or empirically studied. Explanatory framework describes the theoretical or conceptual underpinnings that the author(s) used to explain the findings. The data source dimension is concerned with types of data that were used in the research, including questionnaires, interviews, focus groups, course grades and student assignments. Part of this dimension is the scope of data collection, that is, whether the research was conducted at one postsecondary institution or multiple institutions. This information helps evaluate the generalizability of the findings in quantitative studies. The data analysis dimension shows how the collected data were analyzed and includes four categories. The “quantitative simple” category includes articles that used statistical analysis methods that are typically covered in a statistics introduction course at the postsecondary level, usually including descriptive statistics and comparisons of means, such as t-test and ANOVA. The “quantitative complex” category encompasses articles that used statistical analysis methods that are typically covered in intermediate or advanced statistics courses, usually involving multivariate analysis techniques, such as regression analysis and factor analysis. The “qualitative simple” category includes articles that typically applied a thematic analysis to qualitative data whereas the “qualitative enhanced” category includes articles that denoted a clearly specified analysis process, such as phenomenography or grounded theory.

3. FINDINGS

In this section, I will first report the overall picture of the reviewed 142 articles with respect to their research topics and the nature of the paper. Then I will present the patterns that emerged from the review of the articles in each journal in terms of all five dimensions—research topics, the nature of the article, use of explanatory framework, data source and data analysis.

As shown in Table 2, 78% of the reviewed articles can be placed in one of the three categories identified by Borrego and Bernhard [11]. Articles under the category of instructional or curriculum development focused on educational interventions introduced to courses, programs or curricula and were written from the perspective of instructors and faculty members; only some of them assessed the impact of the interventions on student learning. Articles under the category of student learning and assessment typically examined engineering students’ learning experiences and perceptions, and identified contributing factors to student academic achievement or skill development. Articles under the category of retention and diversity of engineering students attempted to address how to retain engineering students in undergraduate and graduate studies and investigated experiences of female and other minority students. In addition, researchers also studied engineering education research itself (including EER methods and EER communities) and academic and career pathways of engineering students, examined admission process of engineering students and engineering workplace practice, and validated new instruments.

Further, while more than three-fifths of the articles were empirical research papers, about one-fifth were case reports on how a new method or tool was implemented in a particular educational setting. About one-tenth were position papers that advocated an insight or proposed a new method or tool, and only 1% were theory papers. In addition to these four types of research identified by Malmi and her colleagues’ methodological taxonomy, 4% were literature reviews. Case reports, position papers and theory papers were more likely to be published by the AJEE, EJEE and JEE whereas the JEE articles tended to focus on empirical research, as Table 3 suggests. Approximately half of the empirical papers contained their explanatory frameworks.

3.1 AJEE articles

The top two topics of the 10 AJEE articles published in 2018 were methods in engineering education research (3 articles) and instructional/curriculum development (3 articles). Regarding the nature of articles, four were empirical papers and four were position papers, including three proposing new methods for qualitative or quantitative data analysis. Only one article provided an explanatory framework. One empirical paper alone involved participants in different research settings and only one paper used complex techniques in quantitative analysis.
3.2 EJEE articles

Within the 60 EJEE articles published in 2018, the top two topics were instructional or curriculum development (43%, 26 articles) and student learning (33%, 20 articles). Seven other topics spread out in the remaining 27% (14 articles), including retention and diversity of engineering students, career pathways of engineering students, engineering practice and engineering aspirations of secondary school students.

Regarding the nature dimension of these articles, 60% (36 articles) were empirical studies, 27% (16 articles) were case reports, 8% (5 articles) were position papers, 3% (2 articles) were literature reviews, and 2% (1 article) was a theoretical paper. All the case report articles were under the topic category of curriculum or instructional development. All the articles that addressed the topic of student learning were empirical studies.

Of the empirical papers, 44% used explanatory framework although some of the explanatory frameworks were not grounded in solid theoretical underpinnings. The majority of these studies were conducted within a single research setting (i.e., one course, one program, or one university) (72%); and employed simple quantitative or qualitative data analysis techniques (75%). Fifteen of the 16 case report articles provided evaluation data.

3.3 IJEE articles

Of the 48 articles in two of the six issues of the IJEE in 2018, 63% (30 articles) addressed instructional or curriculum development issues, and 21% (10 articles) were concerned with student learning or learning assessment. Of these articles, 52% (25 articles) were empirical papers, 35% (17 articles) were case reports, and 8% (4 articles) were position papers.

Although most of the articles on instructional/curriculum development issues were case reports, this topic was also studied in empirical paper, position paper and theory paper; and one article was a literature review. All the ten articles on student learning or assessment were empirical studies.

Of the empirical papers, 44% (11 articles) included an explanatory framework, 28% (7 articles) were conducted in multiple research settings, 44% (11 articles) used complex techniques for data analysis (mostly quantitative).

A striking feature of the IJEE publications is that their authors are from across the world; and this geographic diversity of authorship is not seen in other three journals examined in this paper.

3.4 JEE articles

Of the 24 JEE articles published in 2018, 46% (11 articles) were about student learning, 17% (4 articles) addressed the topic of retention and diversity of engineering students, and 13% (3 articles) were devoted to instrument validation, 8% (2 articles) were concerned with admission of engineering students and
engineering practice respectively, and 4% (1 article) were about engineering education research and academic pathways of engineering students respectively. The student learning category mostly examined contributing factors to student academic achievement or skill development (4 articles) and investigated student learning processes (3 articles). Three of the four articles that focused on retention and diversity examined gender issues in engineering education settings.

Regarding the nature dimension, 92% (22 articles) were empirical papers and 8% (2 articles) were literature review on specific engineering education issues. Of the 22 empirical papers, 73% (16 articles) included explanatory frameworks whereas the remaining 27% (6 articles) did not use a theoretical or conceptual framework. While a variety of explanatory frameworks were used by the 16 articles, social cognitive theories (3 articles) and learning theories (2 articles) were used more often than other frameworks; this was likely related to the relative high number of articles that addressed student learning.

Regarding data sources, in addition to questionnaires and interviews that were most commonly used, institutional records for student grades and attendance, student work, mental process assessment were also collected by a small proportion of the 22 empirical papers. Close to half (41%) of the empirical papers involved more than one research setting.

Regarding data analysis methods, of the 22 empirical papers, 54% were quantitative and 45% were qualitative. Strikingly, 83% and 80% of these studies used “quantitative complex” and qualitative advanced methods for data analysis. The papers under the “quantitative complex” category used multivariate statistical techniques such as regression analysis (linear or logistic), factor analysis, multilevel modeling and structural equation modeling. Those papers under the “qualitative advanced” category used phenomenological (2), ethnography (2), lexical analysis, narrative method (1), critical theory (2), collaborative inquiry (1) for analysis. In particular, the novelty in using qualitative methods in EER was exemplified by one study [12], which drew upon critical theory and the narrative approach to examine the marginalized educational experiences of a female undergrad engineering student through one longitudinal interview. The large proportion of published qualitative studies and particularly the inclusion of research conducted in paradigms other than (post)positivism suggest that the JEE is in a process of shifting away from the dominance of positivist quantitative research in its publications.

4. DISCUSSION

The review of articles published by four major engineering education journals in 2018 corroborates that EER has become a systematic and evidence-based field of inquiry [2, 13]. However, the comparison among the four journals reveals that EER exhibits varied profiles in different engineering education journals in all the five dimensions being examined in this paper. In terms of research topics, although teaching and learning issues dominate the landscape of EER, the JEE has a clear tendency of publishing articles related to student learning whereas the other three journals seem to slightly favour articles addressing instructional and curriculum development issues over student learning issues. In terms of the nature dimension, although empirical studies are the predominant mode, EER has been published via other formats of case reports, position papers, theory papers and literature reviews. Existing as they are, all these formats are presumably legitimate ways of conducting EER. However, articles in these formats do not appear to be attractive to the JEE. This may be because practice-focused articles are considered by the other journal of the American Society for Engineering Education—Advances in Engineering Education. In comparison, the other three journals do not have this scholarliness-practice divide. Noteworthily, there appears to an interaction between research topics and types of research conducted. That is, research focusing on student learning tends to be empirical in nature while research on instructional and curriculum development is often written up as case reports. In terms of data analysis methods, the JEE articles appear to be most sophisticated methodologically among the four journals as a good proportion of them used an explanatory framework to guide the analysis, drew upon data sources from more than one research setting, and resorted to complex and advanced methods for data analysis.

Several patterns and trends can be identified about EER from the analysis in this paper. First, the analysis attested to the top three EER areas as specified by Borrego and Bernhard [11]: instructional or curriculum development, student learning and assessment, and diversity and retention of engineering students. However, the identified topics have also gone beyond this initial list of three and encompassed other areas such as engineering education research itself, career and academic pathways of engineering students, admission issues, instrument validation and engineering practice. Second, single-setting research is prevalent in EER; some appear to be action research. This is likely to be related to the fact that many articles, particularly those on the topic of instructional and curriculum development, often addressed engineering
education issues in a particular institutional context. Although these single-setting studies provide useful insights for practice, their generalizability is limited and how to extend the research findings to broad communities can be a challenge for researchers. Third, less than half of the empirical studies have included an explanatory framework. As a theoretical or conceptual framework serves to strengthen the explanatory power of an article and improves its analytical generalizability, lack of such a component in many articles either demonstrates an existing challenge in EER or raises a question about its absolute necessity to conducting EER. Fourth, methodological breakthroughs have been made in some studies by means of using alternative ways other than the conventional positivist quantitative analysis in EER. This suggests that the field of EER has become increasingly diverse in research methodology.

Further, the findings from this methodological review reveal two interrelated tensions existing in EER. One is the contested tension between scholarship and practice. The dualism is explicitly juxtaposed in the scope statements of the AJEE and the EJEE. The tension between the two is also reflected by empirical studies and other formats of EER such as case reports, position papers and theory papers that are published or excluded by engineering education journals. The JEE appears to associate empirical research with scholarship or scholarliness as it predominantly publishes empirical studies, supplemented by a small number of literature review papers. However, one may challenge this notion that scholarly research is solely empirical.

The other tension disclosed by the findings is between two methodology discourses as identified by Beddoes [14]: rigour and methodological diversity. There have been calls for rigour in the field of EER [15, 16]. Streveler and Smith [16] adopted the guidelines on “scientific research in education” used by the US National Research Council and introduced the following criteria of rigour to the field of EER: 1. Pose significant questions that can be answered empirically. 2. Link research to relevant theory. 3. Use methods that permit direct investigation of the question. 4. Provide a coherent and explicit chain of reasoning. 5. Replicate and generalize across studies. 6. Disclose research to encourage professional scrutiny and critique. This set of criteria delineates a picture of rigorous engineering education research that is characteristic of being empirical, strong in theoretical underpinnings, and methodologically sound (most likely quantitative), with high generalizability. However, the findings of this review present a different picture of methodological diversity, in which four other types of EER papers, in addition to empirical studies, were published, half did not include an explanatory framework, a number of them were qualitative studies, and a range of methodologies (“simple” or “complex” / “advanced”) were used in data analysis. Although Malmi et al.’s [8] designed their methodological taxonomy on the basis of the framework of scientific research in education [17], as Streveler and Smith [16] did, they appreciated the value of methodological richness to the developing maturity of the EER field and the taxonomy itself is open to methodological diversity. In a similar vein, the findings of this exploratory review paper testify the methodological diversity discourse embedded in recent EER papers while recognizing the sophisticated scientific thinking as exhibited in many of the JEE publications in 2018. This rigour-diversity divide may be partially explained by different traditions for social research embraced by US-based researchers and those who were trained elsewhere. As Borrego and Bernhard [11] revealed, the European tradition generally privileges the significance of authentic, complex problems over the empirical evidence whereas the converse tends to happen to the US research approaches. The contested differences have implications for how to define quality and what constitutes quality in EER. Do engineering education researchers want to uphold one single standard of quality to fit all types of EER, or a multi-dimensional set of quality standards so that different types of EER can be evaluated equitably? Some EER scholars have attempted to address these questions by contending for other ways out. Bernhard and Baillie [18] have encouraged the EER community to “begin to negotiate criteria for quality” (p. 2738). Riley [19] has suggested that the EER community support each other in recognizing other ways of knowing to critique rigour and “find a place to start to build a community for inclusive and holistic engineering education” (p. 263).

Finally, the methodological review sheds light on the epistemic relations and social relations that essentially underlie the knowledge-knower structures of the EER field. In his book Knowledge and Knowers, Karl Maton (2014) conceptualizes intellectual fields by their knowledge-knower structures; and uses a set of specialization codes to conceptualize the underlying principles of an intellectual field. These specialization codes are defined by epistemic and social relations, that is, “epistemic relations between practices and their object or focus (that part of the world toward which they are oriented); and social relations between practices and their subject, author or actor (who is enacting the practices)” (p. 29). In this light, the knowledge practices of the intellectual field of EER can be viewed as comprising knowledge-knower structures that specialize actors and discourses in a way that provides
a means of conceptualizing the distinct characteristics of the EER field. Klassen and Case [20] analyzed a selection of influential papers in the field of EER and found that EER work produced by US-based researchers features strong boundaries on both social relations and epistemic relations in that researchers much be engineers to establish legitimacy in knowledge claims and EER distinguishes itself from other fields of educational research. The methodological review in this paper sheds a different but complementary light on this discussion of knowledge-knower structures of EER. The findings reveal that engineering education researchers (that is, knowers) in different jurisdictions seem to have approached EER in different ways; there appears to be a distinct geographical boundary on social relations. Although these researchers have used a wide range of methods to build knowledge claims for the EER field, there seems to be a distinct geographical boundary on epistemic relations between knowledge claims and objects of knowledge. Arguably, behind the seemingly geographical distinction underlie different research traditions and concomitantly what constitutes quality educational research.

5. Conclusion

This exploratory methodological review of articles published in 2018 by four major engineering education journals has gone beyond satisfying the curiosity of a new engineering education researcher like myself toward making inquiries about several questions that are critical to the further development of EER as an educational and intellectual field. These questions include: What constitutes quality in EER? What should standards of quality for EER look like? How can the EER community break away with the concept of rigour rooted in scientific research in education and welcome other ways of knowing? Sociologically, what features the knowledge-knower structure of the field of EER? And, how can this understanding contribute to the endeavours to build the legitimacy of EER and enhance the quality of engineering education research? This paper also reveal that knowledge building in EER is socially situated and bounded, and draws upon the traditions and practices of different EER communities. It seems paramount that more inclusive standards of quality and more malleable criteria for rigour need to be in place if EER communities of different jurisdictions are to build an truly internationally connected field of engineering education research.

References:


