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A Text-Mining-based Review of Articles published in ASCE Journal of Professional Issues in Engineering Education and Practice

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Abstract

This study extends the existing reviews targeting on *Journal of Professional Issues in Engineering Education and Practice* (JPIEEP) by incorporating the text-mining review methodology. A total of *1,810* papers published in JPIEEP since 1982 were selected as the literature sample. Dividing the whole sample into four sub-samples according to publication time spans, this review indicates that literature published before 2000, especially articles from the 1982-1991 period emphasized more civil engineering related practical and practical issues (e.g., legislation). Since early 2000s, literature from JPIEEP has been focusing more on engineering education-based research, such as teaching methods and undergraduate education. Specifically, more recent studies show emerging topics of the education and practical subjects (i.e., BIM and sustainability), pedagogical approach (i.e., problem-based learning, active learning, simulation, teamwork, and distance education), and diversity issues. Accordingly, future research directions are proposed, such as integration of emerging pedagogical methods in the emerging subjects (e.g., BIM). This study contributes to review of engineering education and practice by demonstrating that the text-mining approach could be reproduced to assist other review-based studies. Finally, this Technical Note addresses questions regarding the latest research topics and proposes directions for future scholarly work.

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Introduction

Journal of Professional Issues in Engineering Education and Practice (JPIEEP) publishes both engineering education and professional practice related papers. However, over the years it has evolved in its scope more towards education (Barry and Roberts, 2016). It has also been indicated by Barry and Roberts (2016) that there has been more education-based scholarly research in the field of civil engineering. Continuing from the study of Barry and Roberts (2016), further work can be performed to specifically identify the mainstream and latest research topics published in JPIEEP, as well as how these research topics change over time.

Although Wankat (1999, 2004) and Whitin and Sheppard (2004) provided reviews of several papers published in JPIEEP, there have been limited studies to continue the review in this journal to provide the latest trend analysis of main research topics. Another drawback of many existing review-based studies (e.g., Li et al., 2014) is that they have been based on manual reviews prone to subjectivity and restricted in their lack of reproducibility (Hosseini et al., 2018). This subjectivity includes identifying keywords in the selected literature sample. A text-mining-based review method proposed by van Eck and Waltman (2014) could minimize the subjectivity and also reduce human errors. A text-mining-based review introduced in this study can also form a part of the systematic review approach recommended by Borrego et al. (2014) in terms of uncovering patterns, connections, relationships, and trends across multiple studies. It can also complement the analytic review approach conducted by Hurwitz et al. (2016) by quantitatively measuring the popularity and impact of research topics in a given literature sample.

The more recent review-based study of Barry and Roberts (2016) provided a comprehensive review of publications in JPIEEP by offering the prescriptive data such as the

citation rates, author affiliations, frequency of keywords, and international collaborations. Researchers perceive the work of Barry and Roberts (2016) more in the general view, which was based more on the overall movement of the journal indicated by prescriptive data. For example, it was concluded that the citation rate of articles published by the journal had increased, contributing to the increased impact factor of the journal (Barry and Roberts, 2016). This review-based study aims to extend the earlier review work performed by Barry and Roberts(2016) in a more specific and technical perspective, particularly: (1) this study targeted technical keywords in the literature sample of JPIEEP by addressing the latest research topics since 2010. A comparative study of main keywords from papers published in different periods. These keywords would be more technical and specific, e.g., "problem-based learning" instead of "engineering education", or "geotechnical engineering" instead of the general term "civil engineering"; (2) this study applies a text-mining approach to allow automatic computation of frequency and citation related measurements for keywords and documents. Using a visualized and quantitative method, this new review methodology also enables a more in-depth analysis of main research keywords in JPIEEP; (3) this study further provides a summary of most influential publications from JPIEEP measured by not only total citation or frequency, but also normalized citation, which was a quantitative measurement of a publication or keyword's influence by correcting the bias that older publications have had more time to receive citations (van Eck and Waltman, 2017). Overall, this Technical Note contributes to the body of knowledge in civil engineering education and practice by utilizing the database of JPIEEP in that: (1) it provides the in-depth analysis of the emerging research focuses and influential studies; and (2) it serves as a guide for scholars by offering an overview of the research trend and recommending future research topics. The text-mining-based review approach used in this study could also be applied to other review-based research.

Text-mining-based review method

The text-mining-based review method adopted in this study incorporated the citation analysis (e.g., normalized citation). It started with downloading all JPIEEP articles which had been indexed in *Scopus*, the mainstream database of scientific literature. All types of *Scopus*-indexed papers from JPIEEP, including Technical Papers, Technical Notes, and Case Studies digitally available since 1982, were adopted as the literature sample saved in *CVS*-based data file. Due to the electronic data availability in *Scopus*, papers published before 1982 were not included for the text-mining-based review. The database of the sample was then uploaded into *VOSViewer* (van Eck and Waltman, 2010), a text-mining tool to conduct the literature review. According to van Eck and Waltman (2014), *VOSViewer* fits the purpose of visualizing larger networks with special text mining features. Consistent to the data categories adopted in the review conducted by Pietroforte and Stefani (2004), the abstract, keywords, and article title were saved in *CVS* files for the review. A total of *1,810* papers were downloaded from *Scopus*, with the first JPIEEP paper indexed in 1982. This whole literature sample was then divided evenly into four sub-samples, namely the subsample of papers published from 2010 to the end of 2018,from 2001 to 2009, from 1992 to 2000, and from 1982 to 1991. Each sub-sample of literature was based on a nine-year period. Although the sub-sample from 1982 to 1991 covers a ten-year period, only four papers published in 1982 were indexed in Scopus, allowing them to be combined with the nine-year span until 1991. The aim of dividing into four sub-samples was to allow the comparative analysis of research keywords to explore the evolvement of research topics in the past decades. Besides the keyword analysis, most influential studies published in JPIEEP measured by occurrence (i.e., frequency) and normalized citation were also identified, enabling a further in-depth analysis of the research focuses in JPIEEP.

Review results

A total of *390*, *414*, *462*, and *544* papers fell into the sub-samples of literature published in the periods of 1981-1991, 1992-2000, 2002-2009, and 2010-2018 respectively. Following the text-mining-based analysis in *VOSViewer*, the four sub-samples of literature are visualized of their frequently studied keywords in Figs.1-4, respectively.

<Insert Fig.1 here>

<Insert Fig.2 here>

<Insert Fig.3 here>

<Insert Fig.4 here>

It should be noticed that these general keywords such as engineering education and professional practice are excluded in the text-mining process, because they are expected scopes for any studies published in JPIEEP. The font and circle size indicate the frequency of the given keyword being studied in the sub-sample. The closeness between any pair of keywords can be indicated by their physical distance in the visualized network. Keywords in both figures are also categorized into clusters defined by different colors, meaning that the same cluster of keywords have a higher chance of being co-studied. Comparing the keywords in Figs.1-4,, it could be indicated that the two sub-samples of literature published after 2001 have been focusing more on construction related education and practice, differing from the 1982-2000 period literature which focus more on the general civil engineering education. Specifically, the 1982-1991 period literature cover more civil engineering education and practice issues related to teaching, training, practice, project management, and other professional issues (e.g., social and public aspects). Consistent with the study of Barry and Roberts (2016) who found that more recent studies published in JPIEEP had been more related to education-based research, it is also identified in this study that literature published in JPIEEP has been focusing more on pedagogy-based studies rather than practical issues especially since early 2000s. Literature published from 1982 until 2009 have more emphasis

121 on legal issues (e.g., litigation, legislation, and dispute). However, the more recent literature
122 since 2010 has been focusing more on educational techniques and technological evolvement.
123 Compared to Barry and Roberts (2016), this study provides a more technical view of keyword
124 evolvement in JPIEEP. Specifically, BIM has been gaining the momentum in the recent
125 decade by being incorporated in the curriculum. More digital or electronic technologies
126 involved in engineering education can be seen more recently, in terms of virtual reality,
127 simulation, and distance learning. Other emerging research topics since 2010 could also be
128 found, such as education and practice of women, distance education, and teamwork. More
129 quantitative measurements of main research keywords between these two time periods can be
130 found in Table 1.

131 <Insert Table 1 here>

132 Keywords listed in Table 1 follow the value of average normalized citation, which is the
133 measurement to evaluate the impact of the given keyword on the global academic community.
134 It is calculated by dividing the total number of citation of the given keyword by the average
135 number of citation published in the same year. The normalization corrects the bias or
136 misinterpretation that earlier publications have more time to receive citations than more
137 recent ones (van Eck and Waltman, 2017). The normalized citation shown in Table 2 is
138 calculated in the consistent approach and conducted in *VOSViewer*. More details of applying
139 the normalized citation in literature can be found in Jin et al. (2018). Consistent to the
140 visualized networks in Figs.1-4, the main differences of research focuses among the four time
141 periods are: BIM has replaced safety and other civil engineering practical issues (e.g., water
142 supply) to be the most influential keyword during the recent decade; JPIEEP has become
143 more international by having more published work coming from China; sustainability has
144 become a focus in engineering education and practice; teaching methods have more involved
145 problem-based learning, active learning, and simulation; more studies have stressed diversity

and minority (e.g., women). Table 2 showcases the most influential studies measured by the total citation and normalized citation (Norm. citation).

<Insert Table 2 here>

Table 2 shows results consistent with the keyword analysis in Table 1. For example, BIM and its relevant IT technologies (e.g., augmented reality) have become mainstream and influential topics in engineering education and practice. Zou et al. (2019) stressed the need for optimizing BIM education resources to bridge the gap between academic research and industry practice. Sustainability and safety have also showed the impacts in engineering education. Safety, specifically employee health and wellbeing, has been the research focus throughout all the decades. Earlier studies over a decade ago had emphasized nurturing the next generation of civil engineering practitioners through specific ways such as industry-university partnership (Tener, 1996).

Summary of observations

This study extends existing review-based research targeting on *Journal of Professional Issues in Engineering Education and Practice* (JPIEEP) by introducing the text-mining-based review methodology, which could be applied in other reviews in the future. A total of *1,810* documents indexed in *Scopus* were adopted as the literature sample, which was further divided into four sub-samples based on the year of publication. The text-mining-based review revealed the information regarding: (1) the evolvement of research keywords in engineering education and professional practice; and (2) the most influential papers published in JPIEEP. It was found that compared to earlier studies, research published before 2000 targeted more on general civil engineering education and practical issues. . Since early 2000s, published work in JPIEEP has focused more on construction related education, and the education is more specifically divided into undergraduate and graduate levels, with the former more highlighted and receiving more attention compared to the latter. More differences are also

found among the four publication periods. The published work since 2010 in JPIEEP has targeted more on specific education and practical themes (i.e., BIM and sustainability), pedagogical approach (i.e., problem-based learning, active learning, simulation, teamwork, education & practice integration, distance education), and diversity issues including women in education have been gaining the momentum. Generally, the earlier published work (i.e., 1982-1991) emphasizes more on civil engineering professional issues (e.g., social, professional, and practice). Afterwards, more education-based topics have been studied such as teaching methods. Following the research topic review adopting the text-mining approach, the current review aligns with the upcoming update of the focus of JPIEEP related to education-based research. Future research directions can be recommended in engineering education and practice, including but not limited to: (1) integration of pedagogical methods (e.g., problem-based learning) in the emerging subjects (e.g., BIM); (2) investigation of the diversity issue (e.g., demographic factors) in terms of their effects in engineering education; and (3) distance learning enhanced by IT, such as Internet-of-things involving BIM. Only electronically available literature indexed in *Scopus* since 1982 was included for the text-mining review. Therefore, this study only reflects the change of research topics published in JPIEEP over time from 1982 to the end of 2018.

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Data Availability Statement

Data generated or analyzed during the study are available from the corresponding author by request.

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275 Table 1. Quantitative analysis of keywords studied in the four literature samples from *JPIEEP*

Influential keywords occurring during the period of 2010-2018			**Influential keywords occurring during the period of 2001-2009**			**Influential keywords occurring during the period of 1992-2000**			**Influential keywords occurring during the period of 1982-1991**		
Keyword	**Occ.**	**Ave. Norm. Citation[1]**	**Keyword**	**Occ.**	**Ave. Norm. Citation**	**Keyword**	**Occ.**	**Ave. Norm. Citation**	**Keyword**	**Occ.**	**Ave. Norm. Citation**
BIM	13	3.87	Safety	6	2.54	Technical Presentations	10	3.13	Water Supply	4	5.75
Service Learning	4	3.58	PM	7	2.45	Communication	9	2.65	Management	13	4.06
China	9	2.39	Risk	6	2.26	Teaching	43	2.27	Construction Industry	20	3.97
Virtual Reality	4	2.27	HK	6	2.19	Strategic Planning	16	2.23	Environment	11	3.78
Case Study	4	1.74	Learning	12	2.10	Management	12	1.99	CE PM	9	3.36
Sustainability	39	1.69	Curricula	44	1.97	Information Dissemination	9	1.95	Research	5	3.21
Curricula	14	1.62	Accreditation	7	1.79	Philosophical Aspects	9	1.95	Technology	13	2.81
Structural Equation Modeling	4	1.62	Professional Development	12	1.77	Computer Aided Instruction	10	1.93	Teaching	19	2.67
Contractors	4	1.61	Survey	5	1.71	Education	8	1.91	Contracts	6	2.50
Multidisciplinary	4	1.41	Structure	6	1.62	Engineering	18	1.85	CE Education	14	2.30
PBL	6	1.41	Training	11	1.61	PM	23	1.82	Social Aspects	13	2.21
Simulation	5	1.27	Litigation	11	1.57	Engineering Research	15	1.76	Ethics	10	1.92
Active Learning	7	1.23	International	6	1.57	Construction	48	1.74	Economics	8	1.86
Safety	5	1.22	Construction	86	1.49	Civil Engineering	144	1.68	Quality Control	4	1.80
Research	8	1.15	Contract	21	1.46	Competition	13	1.68	Civil Engineering	133	1.66
Risk Management	4	1.12	Communication	5	1.42	Personnel Training	26	1.65	Engineers	53	1.58
Collaboration	4	1.09	Sustainability	20	1.37	Professional Aspects	113	1.59	Legislation	14	1.38
Construction	50	1.03	Claim	14	1.36	Public Policy	35	1.57	Training	8	1.35
Teamwork	7	1.01	Teaching	17	1.36	Supervisory	8	1.55	CE Practice	41	1.32

			Methods			Personnel					
Structure	7	1.00	Geotechnical	7	1.34	Sustainability	24	1.52	Information	8	1.08
Teaching	15	0.97	Education-Practice Interchange	7	1.33	Codes (Standards)	16	1.52	Public Works	11	0.91
PM	7	0.94	Undergraduate Study	21	1.30	Software	8	1.50	Hazardous	5	0.60
Design	6	0.89	Contractor	10	1.27	Structural Design	31	1.40	Writing	6	0.59
Innovation	4	0.84	Licensing	5	1.26	Standards	27	1.39	Registration	4	0.58
HK	4	0.81	Delay	6	1.26	Economic And Social Effects	26	1.37	Bridges	4	0.58
Distance Education	5	0.79	IT	9	1.22	Societies And Institutions	55	1.28	Environmental Engineering	5	0.39
Women	6	0.76	Arbitration	6	1.21	Planning	11	1.25	Liability	8	0.34
Transportation	9	0.75	Research	6	1.11	Economics	19	1.21	Computer Aided	4	0.29
			Liability	9	1.09	Laws And Legislation	36	1.19	CE Public Policy	7	0.11
			Software	6	1.06	Environmental Impact	18	1.17	Urban Planning	7	0.11
			Legal	21	1.05	Social Aspects	45	1.16			
			Dispute	25	1.04	Technology	18	1.16			
			Ethics	11	1.00	History	10	1.09			
			Design	5	0.98	Public Works	10	1.08			

[1] The Ave. Norm. Citation (i.e., Average Normalized Citation) or Norm. citation shown in Table 2, represents the normalized number of citations of a keyword or a paper.

280 Table 2. A summary of most influential studies published in JPIEEP

Document	Title	Total citation	Norm. citation
Becerik-Gerber, Ku and Jazizadeh (2012)	BIM-enabled virtual and collaborative construction engineering and management	48	6.65
Chen et al. (2011)	Use of tangible and augmented reality models in engineering graphics courses	41	3.96
Becerik-Gerber and Kensek (2010)	Building information modeling in architecture, engineering, and construction: Emerging research directions and trends	72	5.59
Wu and Low (2010)	Project management and green buildings: Lessons from the rating systems	57	4.43
Sacks and Barak (2010)	Teaching building information modeling as an integral part of freshman year civil engineering education	86	6.68
Choudhry et al. (2008)	Safety management in construction: Best practices in Hong Kong	45	6.40
Chau (2007)	Incorporation of sustainability concepts into a civil engineering curriculum	73	7.37
Edkins and Smyth, (2006)	Contractual management in PPP projects: Evaluation of legal versus relational contracting for service delivery	42	4.83
Chinowsky et al. (2006)	Developing knowledge landscapes through project-based learning	52	5.98
Toole (2005)	Increasing engineers' role in construction safety: Opportunities and barriers	56	5.76
Russell and Stouffer (2005)	Survey of the national civil engineering curriculum	50	5.14
Jeffers et al. (2004)	Understanding K-12 engineering outreach programs	137	16.15
Steinemann (2003)	Implementing sustainable development through problem-based learning: Pedagogy and practice	84	12.00
Chan et al. (2002)	Educating the 21st century construction professionals	46	5.98
Bowman and Farr (2000)	Embedding leadership in civil engineering education	46	3.14
Johnson (1999)	Problem-based, cooperative learning in the engineering classroom	82	5.75
Beder (1999)	Beyond technicalities: Expanding engineering thinking	67	4.70
Bordogna (1998)	Tomorrow's civil systems engineer - The master integrator	49	6.45
Sabatini (1997)	Teaching and research synergism: The undergraduate research experience	53	7.08
Tener (1996)	Industry-university partnerships for construction engineering education	46	8.32

281 Note: Articles listed in Table 2 follow the publication year, i.e., starting from the most recent publication.
282