Analysis of Advances in Engineering Education Publications (2007-2020) to Examine Impact and Coverage of Topics

Andrew Katz
Department of Engineering Education
Virginia Tech
Blacksburg, USA
akatz4@vt.edu

Cory Brozina
Rayen School of Engineering
Youngstown State University
Youngstown, USA
scbrozina@ysu.edu

Aditya Johri
Department of Information Sciences & Technology
George Mason University
Fairfax, VA
johri@gmu.edu

Larry Shuman
Industrial Engineering
University of Pittsburgh
Pittsburg, USA
Shuman@pitt.edu

Abstract— **In this paper we present findings from analyses of articles published in Advances in Engineering Education (AEE) during the first 14 years (2007-2020) of its publication under the tenure of its founding editor. Our goal in this paper is two-fold: (1) to understand the *impact* of papers published in the journal as measured by citations, and (2) to understand the *coverage of topics* over time. To understand the impact and coverage of topics we qualitatively analyzed abstracts of all the articles published in the journal (N=242) and also used data mining techniques (text network mapping). In terms of impact, the topics that have been cited the most include curriculum development, use of technology for teaching and learning, teaching and learning strategies, and program development. We found that in keeping with the mission of the journal, papers largely reported evidence-driven program or curriculum development outcomes and papers published as part of special issues had the most impact as measured by citations.**

Keywords—quantitative, meta analysis, document analysis

I. Introduction

The journal *Advances in Engineering Education*, henceforth referred to as *AEE* in this paper, was founded in 2005 by the American Society for Engineering Education with a mission to focus on applications rather than research. AEE published its first issue in 2007. Compared to other journals in the field, *AEE* is still a relatively new journal. Its state mission was to "disseminate significant, proven innovations in engineering education practice, including those that are enhanced through the creative use of multimedia (AEE Website).[1]" At the time of AEE's founding, the field of engineering education had been undergoing a strong growth in terms of interest in the topic and efforts to improve the education of engineers. Many of these changes were precipitated by the introduction of outcome-based accreditation criteria (ABET) and through support by the U.S. National Science Foundation for engineering education efforts, including larger center and department-level reform grants.

Editorially, it is important to note that AEE's mission was demarcated from that of ASEE's other publication, *Journal of Engineering Education (JEE)*. Whereas JEE focused on articles that contributed to engineering education by extending theoretical aspects of research and served as an "archival record of scholarly research in engineering education", as a complement, AEE was established to advance innovative applications of engineering education research. With this focus in mind, another major difference with other engineering education publications at that time was that AEE was conceived as a peer-reviewed, online archived journal. As an online publication, AEE was meant to disseminate innovations in engineering education practice more widely especially by leveraging the creative use of multimedia. It would also be open to the public, free of charge.

Since its inception, the journal has had a practice orientation, encouraging authors to use their article to describe "innovative curricula, courses, and teaching practices both within and outside the classroom" but which clearly was built on prior work and Learning Sciences principles. In AEE's mission were also literature reviews; more recently, in addition to full articles, work in progress papers, and commissioned special issues were introduced. Core to its mission though was the idea that, "By focusing on educational developments and practice, *Advances in Engineering Education* complements other engineering education journals which focus primarily on research."

Although a change in editorial leadership is in itself a significant turning point to analyze AEE's impact and coverage, there are other reasons for this analysis as well. We believe there is value in assessing the scholarship within engineering education because, as Culnan has argued, "Researchers can benefit by understanding this process and its outcomes because it reveals the vitality and the evolution of thought in a discipline and because it gives a sense of its future (Culnan, 1986; p. 156)." And in a field that is still seeing substantial growth this understanding is more beneficial as it serves as a foundation for the field and helps in its maturity.

There are many ways to better understand any field or discipline but our strategy of looking at a specific journal comes from the nature of publication venues within engineering education where each of the major journals with "engineering education" in the title has attempted to carve a niche for itself across certain parameters. Wankat, Williams & Neto (2013) compared engineering education research in the European Journal of Engineering Education (EJEE) and JEE through citation and reference analysis and found that while over time both journals have transitioned to become engineering education research journals, JEE had made that transition first. The shift towards research increased the number of citations within these education focused journals, particularly for psychology related papers. This shift was also accompanied by an increase in the number of papers per issue and the number of single author papers but a decrease in citations of science and engineering sources. Overall, the authors found that EJEE had a broader geographic spread of authors compared to JEE which is largely U.S. based. They also cautioned that overall a 'silo' mentality is evident from the journals where scholars who are primarily in the field of engineering education research do not seem to engage with disciplinary engineering researchers who also undertake engineering education research. A few engineering societies publish engineering education work, but it is limited in number and scope. Although many of the nuances of the collaborations within a field are hard to gauge from publications in a specific journal, analyzing what gets published in itself tells us what is valued in the field. AEE, as its mission and purpose make clear, is targeted towards evidence and theory driven applications for engineering education that have been documented to be successful. Therefore, given that it aims to be different from other journals in the field and especially JEE, how has its performance been under the first editor?

II. Approach

In this section we discuss our approach for data collection and analysis. Overall, we had two goals. One, to look at impact by using citation information and second, to look at coverage of topics over a long time period. To understand the impact, we use citations as a measure of how much a paper influenced the field. Analysis of citations is a simple yet effective method for understanding impact - is a paper being read?; more important, is it being referenced and thus shaping other work? Citations are not a perfect measure of impact, papers can be read and discussed without being cited, but in the absence of other forms of data it is the best metric we have available. The problems with citations are well documented and relevant for this work. The primary concern with citation analysis is that there is a wide variation in citations across fields. In relation to engineering education, which is an interdisciplinary field, publications tend to be broader in scope to reach a diverse audience, very similar to the social sciences than the specific engineering disciplines. The emphasis is largely on journal publications which take longer to publish and therefore output, and hence citations, are lower than what one sees in engineering or computing disciplines (Harzing, 2010; Harzing & Alkangas, 2017). Furthermore, the range of journals available to publish engineering education research and applications has been small, although the number has almost doubled in the last decade probably due to increase in the number of faculty and doctoral students in the field, and this limits the number of papers that can be published. This is even true for other fields such as medicine where interdisciplinary fields that are more practice oriented have overall lower citations (van Eck et al., 2013).

The other concern with using citations is the source of the citations. Reporting of citations varies across sources such as Web of Science, Google Scholar, Scopus, and others. We decided to use the count of citations from Google Scholar as opposed to a more traditional bibliometric service like Web of Science. We wanted to be comprehensive in our understanding and therefore used Google Scholar as a metric of citations. Google Scholar is the most inclusive among the different reporting options. According to Harzing and Wal (2008) Google Scholar has a broader range of data sources including those not (well) covered in International Scientific Indexing (ISI). Furthermore, they argue, Google Scholar provides an additional advantage over other platforms in that it is freely available and democratizes citation analysis (Meho & Yang, 2007).

The overall data corpus consisted of 242 papers; all the papers published till 2020. The information about each article in our data included title, year, number of citations, authors, and abstract. Of the 242 papers, there were 72 papers we identified as part of special issues. Table 1 shows the list of special issues we identified. Using the Template

To first determine which topic of papers were being cited most frequently we conducted a qualitative review of all 242 papers to determine a topic category. From this approach there are 18 different codes to categorize papers. We used these groupings to then discuss scholarly impact via citations. As you could imagine, some of the topics came about solely from the special issues, such as data sharing and product archeology.

After our qualitative review, we then take a quantitative approach to analyze the abstracts to see changes over time in how the journal is represented. The quantitative approach utilizes basic natural language processing tools, including text network analysis, which enables a complementary approach to analyzing this corpus. The first method is a high-level look at the top phrases in sequential periods. The second is an analysis of co-occurring phrases in each period. The third is an analysis of how these co-occurring phrases change over time. Each of these are described in greater detail below in the Quantitative Analysis section.

III. Impact Analysis 2007-2020

To understand impact, we undertook a qualitative analysis of the abstracts of all papers published between 2007-2020. As is common in content analysis, three coders independently did a free coding of all the abstracts using multiple codes (they could assign up to four codes for each paper). The codes in this step included words and terms such as: "tutorial activity, concept map, design, interactive tools, project-based, studio format, assessment, capstone, entrepreneurial mindset, reform, among others." The goal was to be diverse enough to capture the content of each abstract but also ensure that the words or terms were related to the field of engineering education. As a next step, the codes were coalesced or grouped into a smaller number of codes (18) and the abstracts were re-coded. The codes were revisited and grouped further to reduce the final list to 18 meta-codes. Two coders independently coded the abstracts using the 18 meta-codes and in the final round assigned only one code to each abstract. Any variations were recorded and then the abstracts were coded again until consensus was achieved on all abstracts. Since we forced the coders to only apply one final code to each paper, even papers that were part of the same special issue may have ended up in a different bucket in our analysis. So, if the primary focus of a paper in the special issue of PK-12 education was technology, they got classified under that heading. If they focused on learning strategies or overall program development, they were coded there. We went with this approach as we wanted to look beyond the special issue title and focus on the paper's primary contribution. Additionally, some codes could be considered within others, such as the 'flipped classroom' code could be embedded within 'teaching and learning strategies' however this would defeat the purpose of our analysis to pull out salient topics within the field. As such if there were enough papers to create a new grouping, such as 'flipped classroom' we felt confident in creating that category.

The final list with details is in Table 1. Overall, our goal was to synthesize meta-level codes and keywords so that an overall picture of the journal would emerge. Later on, in the quantitative analysis, we present more granularity.

Table 3 depicts the number of papers in each category with the number from the special issues listed in parentheses, the category as a percentage of the total number of papers, the total citation counts of all articles in that category, and the citation per paper ratio. The category with the most codes is 'Curriculum Development' with 44 papers and the 'Professional Skills' was the lowest with 2 papers. However, the category with the most citations, 'Use of Technology' was third in the total number of papers with 25. And the category with the highest ratio (total citation count/N) was 'Other'. There are a couple of things that stand out here. First, true to its mission, most papers, and also in some cases the highest impact, comes from papers that are practice oriented. Second, the special issue papers have a high impact in terms of citations per paper as 8 of the 13 codes that include special issue papers have a higher citation ratio than the overall code itself. For example, 'curriculum development' has an overall citation per paper ratio of 9.14 and the special issue papers themselves have a ratio of 10.33 (62/6).

Tables 4-6 list papers with most citations and those with most citations/year. Since citations take some time to show up after a paper has been published, there is a lag. Therefore, the latest published papers represented in Tables 4 and 5 are from 2016[2]. Table 6 shows that there has been a steady build up of papers published over time and it also shows that special issue papers have attracted a lot of citations.

IV. Discussion and Conclusion

Through an analysis of all the papers published in AEE under its first editor, we provide an overview of the impact of articles as well as their coverage of topics. We align this with the mission of the journal at its founding. We clearly see that AEE has created a niche whereby it publishes evidence-based practice papers and has a unique contribution within the realm of engineering education journals. There is also a clear indication that papers on the same topic that are published together as part of special issues have a higher impact especially if the special issue focuses on a current topic of interest within the community. We see that there are certain areas in which work is lacking including data science, artificial intelligence, and various other technology-focused areas, which is not uncommon for a new journal. We also see that the initial years have a large range of coverage and maybe the future will focus on work that builds on prior work within the journal.

Table 2: Codes with Definitions for Qualitative Analysis (Listed Alphabetically)

Code	Description	Example Papers (citations)
Assessment	Paper focuses primarily on assessment of teaching or program.	Borrego, M., Newswander, C. B., McNair, L. D., McGinnis, S., & Paretti, M. C. (2009). Using Concept Maps to Assess Interdisciplinary Integration of Green Engineering Knowledge. *Advances in Engineering Education*, *1*(3). (80) Purzer, S., Fila, N., & Nataraja, K. (2016). Evaluation of Current Assessment Methods in Engineering Entrepreneurship Education. *Advances in Engineering Education*, *5*(1). (41)

Curriculum Development	The paper primarily focuses on course development.	Williams, K., Igel, I., Poveda, R., Kapila, V., & Iskander, M. (2012). Enriching K-12 Science and Mathematics Education Using LEGOs. *Advances in Engineering Education*, *3*(2). (27) Billiar, K., Hubelbank, J., Oliva, T., & Camesano, T. (2014). Teaching STEM by Design. *Advances in Engineering Education*, *4*(1).(27)
Data Sharing	The paper primarily focuses on data sharing.	Ohland, M. W., & Long, R. A. (2016). The Multiple-Institution Database for Investigating Engineering Longitudinal Development: An Experiential Case Study of Data Sharing and Reuse. *Advances in Engineering Education*, *5*(2). (25) Gilmore, R. O., Adolph, K. E., Millman, D. S., & Gordon, A. (2016). Transforming education research through open video data sharing. *Advances in engineering education*, *5*(2). (11)
Department Level Reform	The paper primarily focuses on departmental reform.	Duffy, J., Barrington, L., West, C., Heredia, M., & Barry, C. (2011). Service-Learning Integrated throughout a College of Engineering (SLICE). *Advances in Engineering Education*, *2*(4). (34) Cheville, A., & Bunting, C. (2011). Engineering Students for the 21st Century: Student Development through the Curriculum. *Advances in Engineering Education*, *2*(4). (31)
Design Engineering	The paper focuses primarily on engineering design education.	Howe, S. (2010). Where Are We Now? Statistics on Capstone Courses Nationwide. *Advances in Engineering Education*, *2*(1). (86) Toh, C., Miller, S., & Kremer, G. E. O. (2013). The Role of Personality and Team-Based Product Dissection on Fixation Effects. *Advances in Engineering Education*, *3*(4). (33)
Diversity	The paper primarily focuses on diversity.	Simmons, D. R., & Lord, S. M. (2019). Removing Invisible Barriers and Changing Mindsets to Improve and Diversify Pathways in Engineering. *Advances in Engineering Education*. 7(2). (3)
Entrepreneurship	The paper primarily focuses on entrepreneurship or entrepreneurial mindset.	Duval-Couetil, N., Shartrand, A., & Reed, T. (2016). The role of entrepreneurship program models and experiential activities on engineering student outcomes. *Advances in Engineering Education*, *5*(1). (82) Besterfield-Sacre, M., Zappe, S., Shartrand, A., & Hochstedt, K. (2016). Faculty and Student Perceptions of the Content of Entrepreneurship Courses in Engineering Education. *Advances in Engineering Education*, *5*(1). (24)
Flipped/Hybrid Classroom	The paper primarily focuses on flipped or hybrid classroom formats.	Velegol, S. B., Zappe, S. E., & Mahoney, E. M. I. L. Y. (2015). The Evolution of a Flipped Classroom: Evidence-Based Recommendations. *Advances in Engineering Education*, *4*(3). (144) Clark, R. M., Kaw, A., & Besterfield-Sacre, M. (2016). Comparing the effectiveness of blended, semi-flipped, and flipped formats in an engineering numerical methods course. *Advances in Engineering Education*, *5*(3). (27)
Global Engineering	The paper primarily focuses on a global engineering context.	Jesiek, B. K., Haller, Y., & Thompson, J. (2014). Developing Globally Competent Engineering Researchers: Outcomes-Based Instructional and Assessment Strategies from the IREE 2010 China Research Abroad Program. *Advances in Engineering Education*, *4*(1). (43)
Makerspace	The paper primarily focuses on maker spaces.	Forest, C. R., Moore, R. A., Jariwala, A. S., Fasse, B. B., Linsey, J., Newstetter, W., ... & Quintero, C. (2014). The Invention Studio: A University Maker Space and Culture. *Advances in Engineering Education*, *4*(2). (99)

Other	Miscellaneous	Veenstra, C. P., Dey, E. L., & Herrin, G. D. (2009). A Model for Freshman Engineering Retention. *Advances in Engineering Education*, *1*(3). (134) Mortagy, Y., & Boghikian-Whitby, S. (2010). A longitudinal comparative study of student perceptions in online education. *Interdisciplinary Journal of E-Learning and Learning Objects*, *6*(1), 23-44. (62)
PK-12	Paper focuses primarily on an aspect of K through 12 education related engineering.	Mendoza Díaz, N. V., & Cox, M. F. (2012). An Overview of the Literature: Research in P-12 Engineering Education. *Advances in Engineering Education*, *3*(2). (31) Moore, T., & Richards, L. G. (2012). P-12 Engineering Education Research and Practice. *Advances in Engineering Education*, *3*(2). (28)
Product Archaeology	The paper primarily focuses on product archaeology or product dissection.	Neumeyer, X., Chen, W., & McKenna, A. F. (2013). Embedding Context in Teaching Engineering Design. *Advances in Engineering Education*, *3*(4). (6)
Professional Skills	The paper focuses primarily on professional skills.	Fries, R., Cross, B., Zhou, J., & Verbais, C. (2017). How Student Written Communication Skills Benefit During Participation in an Industry-Sponsored Civil Engineering Capstone Course. *Advances in Engineering Education*, *6*(1). (10)
Program Development	The paper describes the design and/or development of a comprehensive program for teaching and learning (broader than a single course).	Brophy, S. P., Magana, A. J., & Strachan, A. L. E. J. A. N. D. R. O. (2013). Lectures and Simulation Laboratories to Improve Learners' Conceptual Understanding. *Advances in Engineering Education*, *3*(3). (36) Schnittka, C. G., Brandt, C. B., Jones, B. D., & Evans, M. A. (2012). Informal Engineering Education After School: Employing the Studio Model for Motivation and Identification in STEM Domains. *Advances in Engineering Education*, *3*(2). (28)
Teaching/Learning Strategies	The paper describes strategies for teaching or learning.	Hamilton, E., Lesh, R., Lester, F. R. A. N. K., & Brilleslyper, M. (2008). Model-eliciting activities (MEAs) as a bridge between engineering education research and mathematics education research. *Advances in Engineering Education*, *1*(2). (165) Pinder-Grover, T., Green, K. R., & Millunchick, J. M. (2011). The efficacy of screencasts to address the diverse academic needs of students in a large lecture course. *Advances in Engineering Education*, *2*(3). (60)
Topical	The paper focuses primarily on a specific topic or domain (e.g., sustainability, etc.).	Nazzal, D., Zabinski, J., Hugar, A., Reinhart, D., Karwowski, W., & Madani, K. (2015). Introduction of sustainability concepts into industrial engineering education: A modular approach. *Advances in Engineering Education*, *4*(4), n4. (15)
Use of Technology	The paper describes specific uses of technology for classroom applications.	Layton, R. A., Loughry, M. L., Ohland, M. W., & Ricco, G. D. (2010). Design and validation of a web-based system for assigning members to teams using instructor-specified criteria. *Advances in Engineering Education*, *2*(1), n1. (166) Chesler, N. C., Arastoopour Irgens, G., D'angelo, C. M., Bagley, E. A., & Shaffer, D. W. (2013). Design of a professional practice simulator for educating and motivating first-year engineering students. *Advances in Engineering Education*. (62)

TABLE 3: CITATION DETAILS NOTE SI=SPECIAL ISSUE

Code Description	N (SI)	% of Total	Total Citation Count (SI)	Ratio
Curriculum Development	44 (6)	18.2%	402 (62)	9.14
Program development	41(13)	16.9%	315 (125)	7.68
Use of Technology	25(1)	10.3%	528 (6)	21.12
Teaching/Learning Strategies	20(1)	8.3%	354 (15)	17.70
Assessment	18(4)	7.4%	216 (57)	12.00
Entrepreneurship	17 (12)	7.0%	191 (191)	11.24
Other	11(1)	4.5%	297 (5)	27.00
Department Level Reform	10 (9)	4.1%	137 (137)	13.70
Flipped/Hybrid Classroom	9(4)	3.7%	237 (80)	26.33
PK-12	8(6)	3.3%	100 (89)	12.50
Data sharing	7(7)	2.9%	56 (56)	8.00
Design Engineering	6(2)	2.5%	154 (41)	25.67
Global Engineering	6(0)	2.5%	80	13.33
Product Archaeology	6(6)	2.5%	16 (16)	2.67
Topical	5(0)	2.1%	40	8.00
Maker Space	4(0)	1.7%	101	25.25
Diversity	3(0)	1.2%	4	1.33
Professional Skills	2(0)	0.8%	13	6.50

TABLE 4: PAPERS WITH MOST CITATIONS/YEAR

Cites	Authors	Title	Year	Cites/Year
128	Stephanie Butler Velegol, Sarah Elizabeth Zappe, Emily Mahoney	The evolution of a flipped classroom: Evidence-based recommendations	2015	25.6
67	Nathalie Duval-Couetil, Angela Shartrand, Teri Reed	The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes.	2016	16.75
145	Richard A. Layton, Misty L. Loughry, Matthew W. Ohland, George D. Ricco	Design and Validation of a Web-Based System for Assigning Members to Teams Using Instructor-Specified Criteria	2010	14.5
79	Craig R. Forest, Roxanne A. Moore, Amit S. Jariwala, Barbara Burks Fasse, Julie Linsey, Wendy Newstetter, Peter Ngo, Christopher Quintero	The Invention Studio: A University Maker Space and Culture.	2014	13.17
132	Cindy P. Veenstra, L ericC	A Model for Freshman engineering r etention	2009	12
59	Julia Kramer, Shanna R. Daly, Seda Yilmaz, Colleen M. Seifert, Richard Gonzalez	Investigating the Impacts of Design Heuristics on Idea Initiation and Development	2015	11.8
62	Naomi C. Chesler, Golnaz Arastoopour, Cynthia Marie D'Angelo, Elizabeth A. Bagley, David Williamson Shaffer	Design of a Professional Practice Simulator for Educating and Motivating First-Year Engineering Students.	2013	8.86
89	Eric Hamilton, Richard Lesh, Frank Lester, Michael Brilleslyper	Model-Eliciting Activities (MEAs) as a Bridge Between Engineering Education Research and Mathematics Education Research	2008	7.42
75	Maura Borrego, Chad B. Newswander, Lisa D. McNair, Sean McGinnis, Marie C. Paretti	Using Concept Maps to Assess Interdisciplinary Integration of Green Engineering Knowledge.	2009	6.82
78	Ian Cameron, Caroline Crosthwaite, Christine Norton, Nicoleta Balliu, Moses Tadé, Andrew Hoadley, David Shallcross, Geoff Barton	Development and Deployment of a Library of Industrially Focused Advanced Immersive VR Learning Environments.	2008	6.5
51	Amy Orange, Walter Heinecke, Edward Berger, Charles Krousgrill, Borjana Mikic	An Evaluation of HigherEd 2.0 Technologies in Undergraduate Mechanical Engineering Courses.	2012	6.38
55	Susannah Howe	Where Are We Now? Statistics on Capstone Courses Nationwide.	2010	5.5
22	Renee M. Clark, Autar Kaw, Mary Besterfield-Sacre	Comparing the Effectiveness of Blended, Semi-Flipped, and Flipped Formats in an Engineering Numerical Methods Course.	2016	5.5
30	Tershia Pinder-Grover, Katie R. Green, Joanna Mirecki Millunchick	The efficacy of screencasts to address the diverse academic needs of students in a large lecture course	2011	3.33
23	Christine A. Toh, Scarlett R. Miller, Gül E. Okudan Kremer	The Role of Personality and Team-based Product Dissection on Fixation Effects	2013	3.29
25	Priya T. Goeser, Wayne M. Johnson, Felix G. Hamza-Lup, Dirk Schaefer	VIEW – A Virtual Interactive Web-Based Learning Environment for Engineering	2011	2.78
22	Catherine T. Amelink, Glenda Scales, Joseph G. Tront	Student Use of the Tablet PC: Impact on Student Learning Behaviors.	2012	2.75
29	Julie Linsey, Austin Talley, Christina White, Dan Jensen, Kristin Wood	From Tootsie Rolls to Broken Bones: An Innovative Approach for Active Learning in Mechanics of Materials.	2009	2.64
10	James Trevelyan	Extending Engineering Practice Research with Shared Qualitative Data.	2016	2.5

TABLE 5: MOST CITED PAPERS

Cites	Authors	Title	Year	CitesPerYear	ECC	CitesPerYear	CitesPerAuthor	AuthorCount	Age
145	Richard A. Layton, Misty L. Loughry, Matthew W. Ohland, George D. Ricco	Design and Validation of a Web-Based System for Assigning Members to Teams Using Instructor-Specified Criteria	2010	14.5	145	14.5	36	4	10
132	Cindy P. Veenstra, L eriC	A Model for Freshman engineering r etention	2009	12	132	12	66	2	11
128	Stephanie Butler Velegol, Sarah Elizabeth Zappe, Emily Mahoney	The evolution of a flipped classroom: Evidence-based recommendations	2015	25.6	128	25.6	43	3	5
89	Eric Hamilton, Richard Lesh, Frank Lester, Michael Brilleslyper	Model-Eliciting Activities (MEAs) as a Bridge Between Engineering Education Research and Mathematics Education Research	2008	7.42	89	7.42	22	4	12
79	Craig R. Forest, Roxanne A. Moore, Amit S. Jariwala, Barbara Burks Fasse, Julie Linsey, Wendy Newstetter, Peter Ngo, Christopher Quintero	The Invention Studio: A University Maker Space and Culture.	2014	13.17	79	13.17	10	8	6
78	Ian Cameron, Caroline Crosthwaite, Christine Norton, Nicoleta Balliu, Moses Tadé, Andrew Hoadley, David Shallcross, Geoff Barton	Development and Deployment of a Library of Industrially Focused Advanced Immersive VR Learning Environments.	2008	6.5	78	6.5	10	8	12
75	Maura Borrego, Chad B. Newswander, Lisa D. McNair, Sean McGinnis, Marie C. Paretti	Using Concept Maps to Assess Interdisciplinary Integration of Green Engineering Knowledge.	2009	6.82	75	6.82	15	5	11
67	Nathalie Duval-Couetil, Angela Shartrand, Teri Reed	The Role of Entrepreneurship Program Models and Experiential Activities on Engineering Student Outcomes.	2016	16.75	67	16.75	22	3	4
62	Naomi C. Chesler, Golnaz Arastoopour, Cynthia Marie D'Angelo, Elizabeth A. Bagley, David Williamson Shaffer	Design of a Professional Practice Simulator for Educating and Motivating First-Year Engineering Students.	2013	8.86	62	8.86	12	5	7
59	Julia Kramer, Shanna R. Daly, Seda Yilmaz, Colleen M. Seifert, Richard Gonzalez	Investigating the Impacts of Design Heuristics on Idea Initiation and Development	2015	11.8	59	11.8	12	5	5
55	Susannah Howe	Where Are We Now? Statistics on Capstone Courses Nationwide.	2010	5.5	55	5.5	55	1	10

TABLE 6: CITATIONS BY PAPER (IN YEAR PUBLISHED)

Code Description	Total Citations by Year within each Code for Papers Published that Year													
	07	08	09	10	11	12	13	14	15	16	17	18	19	20
Assessment			80	3	25		7	17	6	41	21	16	0	
Curriculum Development	20		59	91	2	70	39	49	21	30	8	12	1	0
Data sharing										56				
Department Level Reform					137									0
Design Engineering				86		8	33		27					
Diversity												3	1	0
Entrepreneurship										136		55		0
Flipped/Hybrid Classroom									144	80		10		3
Global Engineering				14				43	6		11		6	
Maker Space								99					1	1
Other		0	139	62		14	48	29				4	1	

PK-12		6				89		5						
Product Archaeology							16							
Professional Skills						3					10			
Program development	9			36	26	49	66	9	48	60		6	4	2
Teaching/Learning Strategies	23	165	50		60	22		5			24	2	1	2
Topical					4			9	15		12			
Use of Technology	1	14		169	114	66	67	23	54			18	2	
Total Papers Published in Year	4	5	11	18	22	24	20	16	19	25	17	25	14	22

The inception of AEE coincided with the expansion of the field of engineering education in an institutional manner. The first two departments of engineering education were established at U.S. universities in 2004 (Loui & Borrego, 2019) and as of 2021 there are a dozen such departments in the U.S. and many more centers and doctoral programs in engineering education offered as part of another unit (EECR, n.d). A majority of the early departments were converted from units responsible for teaching first-year engineering undergraduates and had expanded their missions to include research and doctoral programs. Outside the United States as well, many institutions now offer doctoral programs in engineering education (e.g., Sweden, Denmark, and Malaysia). At universities without doctoral programs in engineering education, engineering education research is also conducted at teaching and learning centers, in research centers, and by individuals in traditional engineering departments. This growth in the field is crucial to the narrative of new journals, and especially AEE as many of the articles have come as the field has expanded. The articles published in AEE reflect this rise of contributors to the field and the topics covered in the journal, especially the special issues, are reflective of the interests of those who became involved with engineering education from a disciplinary engineering perspective, as well as those who newly gained a doctoral degree in the field.

Special issues have become increasingly common and there is some evidence that they are cited more than papers in a regular issue. Repiso et al (2021) analyzed the impact of special issues through a bibliometric analysis of journals in the field of communication. They analyzed publications from 2015–2019 (sample analyzed included 21,458 articles and reviews, 524 special issues, 418 publishers, and 94 journals) and compared special issues with papers published in regular issues. They found that 19% of articles published in the period studied appeared in special issues and 75% of journals achieved a higher average impact factor with articles special issues than regular issues. Publishers themselves are quick to point out the advantages of special issues to prospective authors and editors. According to Wiley (2019), special issues are highly effective at increasing output of high-quality content, promoting a journal to a wider audience, and as a tool for expanding the scope of a journal. They also state that articles published in special issues are often cited more frequently than articles published in regular issues. Other advantages include broadening the scope of the journal, addressing trending or unaddressed issues, developing new experimental or analytical approaches, and recognizing a prominent figure within the field (Sage, n.d.).

There are some limitations to this study. By focusing primarily on the topical coverage of the journal, we have not paid attention to the demographic and geographic variations among authors and also their relation to topics. We have also not looked at citations per se to better understand their representativeness. Studies have suggested that citation practices have often been biased, especially in the natural and physical sciences but also in the social sciences, and it would be interesting and important to look at them within engineering education. Finally, we have not compared our results with the engineering education taxonomy and this is largely to capture the topics using naturally occurring text in the abstracts. Keywords provided by the authors, especially those restricted by a taxonomy, are more of a deductive characterization whereas our goal was to examine the journal topics inductively. Another set of limitations arises from the quantitative analyses. In several parts, it was necessary to balance interpretability of results with being comprehensiveness. For example, having more terms in each of the text networks would generate a more comprehensive analysis. On the other hand, including more terms makes the diagrams more cluttered and difficult to read or interpret. Because of this, there are some terms that simply do not show up in the analysis because they did not meet the threshold cutoffs that we set for the different analyses.

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