Gender in Engineering Education Research: A Content Analysis of Research in *JEE*, 1998–2012

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Abstract

Background The participation of women in engineering education has increased only slightly since the 1980s, despite the publication of many research studies on gender in engineering education. We think that these studies have not affected practice because researchers have focused too narrowly on how gender relates to engineering education.

Purpose This article investigates whether there is indeed a narrow focus by analyzing how articles published in *JEE* investigate gender. We asked, What are the dominant themes and patterns in the structure of gender research published in *JEE*? We wanted to see how engineering education research articles incorporated gender theory and research methods from the social sciences and education to explore the relationships between gender and engineering education.

Design/Method We conducted a content analysis of gender-related research published in *JEE* between 1998 and 2012. We developed scientometric and other classification categories and applied them quantitatively.

Results Articles related to gender are predominantly quantitative studies that focus on undergraduate students in formal university settings, and incorporate participant identities in the groups of women and men (together) or women, men, and racial minorities (together). Researchers used varied theories of gender, but most of those theories were not used again in later research in the articles analyzed.

Conclusions A greater diversity of theories and designs should lead to a better understanding of gender in engineering education. We suggest areas for future research.

Keywords content analysis; gender; research approaches; research methods

Introduction

Women's representation in engineering education at every level in the United States remains dishearteningly low, with minimal increase over the last decade. Undergraduate programs nationally reported 19.1% of students in fall of 2012 were women (compared with 20.3% in 2004; Yoder, 2013); 22.4% of engineering Ph.D.s awarded in 2013 were awarded to women (compared with 17.8% in 2004; Yoder, 2013); and women represented 14.5% of tenured and tenure-track faculty members in engineering in the fall of 2012 (compared with 10.4% in 2004; Yoder, 2013). Women are severely underrepresented in some engineering disciplines;

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they earn almost 46% of bachelor's degrees in environmental engineering but under 11% of bachelor's degrees in computer engineering (Yoder, 2013).

We have claimed elsewhere (Pawley & Phillips, 2014; Pawley, 2013) that the small number of theories being used in research studies and interventions that focus exclusively on gender and engineering are not sufficient to help increase the number of women in engineering. This article investigates part of this claim by systematically investigating the structure of research on gender and engineering published in the *Journal of Engineering Education* (*JEE*) to characterize the theoretical bases, populations, research questions, methods, and rationales authors used for these research studies. By characterizing the research in *JEE*, we aim to help the engineering education research community start to envision new ways to interrogate women's persisting underrepresentation. Our findings have implications not only for engineering education researchers looking to extend existing research on gender, but also for the reviewers and readers of gender-focused research to help the research community identify research "blind spots."

We investigated the research question, What are the dominant themes and patterns in the structure of gender research published in *JEE*? We describe the results of a content analysis of *JEE*, and situate it in the context of existing research reviews of engineering education research. We describe our method of selecting articles for inclusion, our frame for categorizing them in different ways, and our grounded findings that differ in significant ways from existing content analyses. We then propose implications for the engineering education research community for improving the work of the scholarly community on gender and engineering education.

Background

The field of engineering education has been growing worldwide in recent decades through the development of academic programs, research centers, journals, professional societies, and other institutions (Borrego & Bernhard, 2011; Jesiek, Newswander, & Borrego, 2009). We found 14 systematic reviews that help characterize this growth by summarizing the history, development, accomplishments, or limitations of the field; providing a map of existing research; and revealing obscured or unexplored avenues of engineering education research (EER). Some of these reviews look broadly at EER; others focus on a particular area or topic.

We sorted these reviews of EER into two groups: an "in-depth" group and a scientometric (Hood & Wilson, 2001) group. The in-depth group (Beddoes & Borrego, 2011; Beddoes, 2011; Douglas, Koro-Ljungberg, & Borrego, 2010; Koro-Ljungberg, & Douglas, 2008) examined a smaller set of articles and explored them for themes or patterns; these in-depth reviews generally involved a greater level of inference than those in the scientometric group. Scientometrics are empirical metrics by which researchers try to measure the impact and influence of science and technology; the scientometric group (Beddoes, Borrego & Jesiek, 2009; Hubbard, 2010; Jesiek et al., 2011; Jesiek & Beddoes 2012; Jesiek & Beddoes, 2013; Ihsen, Jesiek, Kammasch, & Beddoes 2010; Tonso, 2008; Wankat, Williams, & Neto, 2014; Wankat, 2004; Whitin & Sheppard, 2004) examined a larger set of articles which relied typically on quantitative analysis techniques or quantification of qualitative aspects.

In the in-depth group, only two articles focused on reviewing gender research. Beddoes and Borrego (2011) analyzed the use of feminist theories in engineering education as represented by *JEE*, the *International Journal of Engineering Education*, and the *European Journal of Engineering Education*. They found that more articles espoused a theoretical frame of liberal feminism, explicitly or implicitly, than other feminist theories. Thus, they argued, the articles they examined do not systematically criticize biased cultural and social constructs, preferring to argue in favor of

equalizing the rights, opportunities, and treatment of women. Our work builds on their article by expanding a focus from feminist theories to gender theories more broadly. The other in-depth article, by Beddoes (2011), explored how gender research articles framed the issue of women's underrepresentation. Beddoes analyzed the same set of journals as did Beddoes and Borrego (2011), but also added many engineering education conference proceedings published between 1995 and 2008. Beddoes identified four ways in which the articles and conference proceedings problematized the issue of underrepresentation: as an issue of economic competitiveness, professional service and representativeness, women's attributes, and social justice. Beddoes (2011) emphasized the importance of recognizing the limitations of different frames for understanding women's underrepresentation in engineering.

In the scientometric group, five articles relate to gender research. Tonso (2008) examined *JEE* articles between 2004 and 2007 and reported that six of seven articles she reviewed took a dichotomous view of gender, and four of those six used gender only as a demographic variable rather than a social construct that is continuously and collectively produced, problematized, and policed. Jesiek and Beddoes (2012) developed the *Diversity in Engineering Bibliography* (http://inesweb.org/dine/), which is a searchable online repository for diversity scholarship in engineering for the years 2005 to 2010, and published a final report about the repository (Jesiek & Beddoes, 2013). Ihsen et al. (2010) provided a preliminary analysis of the bibliography. In an article closely related to this study, Beddoes et al. (2009) reported on the research topics, methods, and career stage of research subjects for gender-related EER across seven journals and conference proceedings for 2005 to 2008. They found both regional overlap and regional variation and focuses in terms of topics and methods. Because their categories overlap with ours, we will be comparing their findings to our own in the Results section.

Method

We selected research articles published in *JEE* for theoretical, methodological, and practical reasons. Methodologically, our research method (Spradley, 1980) required that we select a particular publication for bounding the content analysis. Theoretically, we chose to focus on engineering rather than science, technology, engineering, and mathematics (STEM), because the cultures, work practices, contexts, and, indeed, populations in these other disciplines differ from engineering. We considered the publication cultures and content of *JEE*, the *International Journal of Engineering Education (IJEE)*, the *European Journal of Engineering Education (EJEE)*, the *Annals of Engineering Education* (*AEE*), and the *Australasian Journal of Engineering Education* (*AJEE*) sufficiently different for each to warrant its own investigation. Practically, we found that we could draw significant conclusions from our study of *JEE*, and investigating research published in additional journals would have demanded a good deal more time. Given that *JEE* is the flagship American journal of the developing EER community and the most highly ranked journal focused on EER (assessed by comparing the SCImago Journal Rank indicators for *JEE, IJEE, EJEE, AEE*, and *AJEE* through SCImago, 2007), we believe our findings warrant consideration by the EER community. Other researchers have focused on *JEE* for similar reasons (Borrego, Douglas, & Amelink, 2009; Koro-Ljungberg & Douglas, 2008; Wankat, 2004).

To analyze the *JEE* articles, we employed content analysis. Weber (1990) defined this approach as "a research method that uses a set of procedures to make valid inferences from text. These inferences are about the sender of the message, the message itself or the audience of the message" (p. 9). In order to ground inferences in data, researchers use coding to categorize large quantities of texts into key content areas (Berg, 2007; Weber, 1990). These content

areas can be generated deductively (where some initial set of predefined codes are applied to data; Weber, 1990) or may emerge inductively from data analysis (as discussed by Berg, 2007). Roberts (1997) argued that what differentiates a content analysis from a literary analysis is the inclusion of thorough methodological descriptions and a consistent and systematic development or application of the coding scheme.

We reviewed 15 volumes of *JEE* from 1998 to 2012. We identified articles for inclusion by using a keyword strategy. We downloaded all the articles during this time period and searched at least the title, abstract, and introduction for gender-related words such as *man, men, woman, women, male, males, female, females, gender*, and words with the stems *wom*, sex*, male*, female*, fem*, and masc**. We did not find any instances of other gender terms, such as *cisgender, transgender*, and *agender*, used in any articles. Using the complete text of the selected articles, we then sorted the articles into three categories of importance for gender research: core articles, periphery articles, and unrelated articles.

Core articles have gender as key to their research question(s), or have substantial (50 or more) instances of gendered language within the article, using the keywords listed above. We identified 62 core articles.

Periphery articles do not have gender in their research questions, but do have at least 10 and fewer than 50 instances of gendered language in the body of the article. We identified 70 articles as periphery articles.

Unrelated articles have fewer than 10 instances of gendered language and no gender-related research questions. These are focused on other research topics, such as K-12 engineering or science learning studies. These articles were excluded from the body of articles we went on to analyze.

After this sorting step, we had a body of 132 relevant (core and periphery) articles.

Our frequency thresholds for defining the core-periphery distinction emerged from an iterative analysis of *JEE* articles. We used gendered language as a secondary measure to include articles that had substantial discussion and findings related to gender without having explicit research questions about gender. Our measurement of "substantial discussion" did not factor in gendered terms in tables or figures, where we believed references to gendered terms are likely more tangential to the research, and factoring captions and table entries might artificially inflate the number of gendered terms in an article because they tend to duplicate the body of the text.

Through analyzing the relevant articles, we developed six categories of codes: rationales, theoretical frameworks, methods, research settings, research participant identities and roles, and authors' organizational affiliations and collaborations. Through sustained repeated reading of the articles, we developed operational definitions and subtypes for the research that we thought fell into each category (such as quantitative methods and qualitative methods within the methods category). We developed inductive codes for rationale and for participant identity and role; for the others, we used existing schema or frameworks to define codes more deductively.

We then comprehensively applied the codes and developing subtypes across all the articles (Weber, 1990). We counted instances of research that fell into each subtype to understand the relative frequency or coverage within a category (Weber, 1990). Most of the categories we identified are scientometric measures, except for the theoretical frameworks and rationales that map onto the more in-depth measures.

We divided the workload in this way: The first author initially conceived of the research. The third author initiated the study, identified domain analysis (Spradley, 1980) as a useful

initial method, identified an initial 88 *JEE* articles to analyze from 1998 to 2008, developed the core-periphery distinction and definitions, categorized the identified articles as either core or periphery, and identified an initial set of categories and subtypes. The second author reviewed the work completed by the third author, added articles from 2009 to 2012 into the body of articles, checked all the categories and subtypes, as well as how articles had been classified, and made reclassifications or new claims as necessary. The first two authors substantially contributed to the writing and revision of this article, and engaged in discussions throughout the entire analysis and writing of the article.

Results

We identified 62 articles that have gender as a core research focus, and 70 articles where gender was peripheral. The subsections below discuss the articles' patterns of rationales, theoretical frameworks, methods used, research settings, study participants, and authors' organizational and collaboration patterns.

Rationales

We defined rationales as the justification an article's authors provide for doing the research. Rationale differs from an article's purpose, which we see is to answer specific research questions articulated in the article. We examined only the core articles for this category because periphery articles tended to focus research questions on topics other than gender. We inductively analyzed the first two-thirds (40 articles) to identify common rationales, then applied these categories deductively to the remaining third (22 articles). For each article, we identified up to four rationales; most had three or four. We reanalyzed any articles that exceeded four rationales, so that each article's rationales were those that were most central to the argument. We found a wide variety of explicit rationales in many articles, with many articles having multiple rationales. Therefore, we present results according to how many articles out of the complete body of articles adopted a particular rationale, rather than how frequently a rationale was used, given the range of rationales. We decided to categorize rationales that at least seven (10%) of the core articles used, on the basis that rationales used less frequently could not be distinguished as a research trend.

We had six rationale categories:

Retention Articles focus on mechanisms that help retain women in engineering, or conversely, that repel them. The concepts of retention and underrepresentation are linked in many contexts, but underrepresentation reflects both poor retention and low rates of entry.

Underrepresentation Articles focus on the existence of fewer numbers of women in engineering than men, and note this is a problem.

Improving engineering education Articles refer to modifications to the engineering curriculum, such as using digital platforms for math learning, or focus on the impact of engineering on the broader society.

Gender differences Articles emphasize how men and women experience engineering education differently.

Workforce Articles refer to calls to align the outcomes of engineering education with workforce needs.

New theory Articles propose new theories about EER.

Table 1 shows that the largest fraction of articles used the rationales of underrepresentation and retention. Beddoes et al. (2009) also noted retention was a major research topic. Three of the rationales – underrepresentation, retention, and workforce – are themes used in the *Why So Few?* (Hill, Corbett, & St. Rose, 2010) and *Beyond Bias and Barriers* (National Academies, 2006) reports on gender in STEM. Gender differences, while not as explicitly a focus of many such reports, still appeared 20% of the time. New theory emerges as a minor theme, only appearing in 13% of articles.

Table 1 Rationales

	Core articles (%)
Retention	36.5
Underrepresentation	36.5
Improving engineering education	27
Gender differences	21
Workforce	19
New theory	13

Theoretical Frameworks

We developed the theoretical framework category to encompass the instances where an article makes a connection to an established theory from educational science, cognitive psychology, organizational sociology, women's studies, or any other fields explicitly producing gender theory. For example, an article might cite self-efficacy as guiding the research questions and data collection or constructivism as informing the researchers' approach to data analysis. Not all articles explicitly identify a guiding theory; however, there is clearly what might be considered "little-t theory" (following Gee, 2005), which undergirds the logic of those articles without an explicitly named guiding theory (in contrast with "big-T theory" of named, established theories). We used this little-t theory to classify those articles that do not explicitly articulate a theoretical framework. For example, if an article does not name a theory but it articulates research questions related to retention of women in first-year engineering, we classified this research as subscribing to a "pipeline" theoretical framework (following Berryman, 1983). If such an article investigates classroom climate, we classified it as "chilly climate" (following Hall & Sandler, 1982).

We did not address how articles use theory, whether named or implicit. "Theoretical framework," here, is an inclusive term for the main idea we wanted to investigate: we were interested in seeing what theoretical traditions researchers publishing in *JEE* were drawing on in order to reveal the breadth of their theorization of the concept of gender. We analyzed theoretical frameworks in the core articles only, because the core had the heaviest emphasis on gender research.

Table 2 gives the percentages of articles in which each theoretical framework is used, including pipeline, self-efficacy theory, expectancy-value theory, chilly climate, liberal feminism, constructivism, and other theories. We discuss each framework according to the order in the table.

The pipeline theoretical frame, either explicitly or implied, appears the most in the core articles. We inferred pipeline as a framework if the article focuses on bringing students into engineering or addresses challenges that pushed students out. Pipeline-related articles, therefore, are closely related to retention research.

Table 2 Theoretical Frameworks

	Core articles (%)
Pipeline	48
Other[a]	23
Self-efficacy and expectancy value	13
Chilly climate	8
Liberal feminism	5
Constructivism	3

[a]Theory used only once in body of articles studied.

The category of other contains slightly fewer than half as many articles as pipeline. All of these articles have a theory articulated, but none use a theory that appeared again in any other article. Some of these infrequently used theories are Foor, Walden, and Trytten's (2007) use of critical cultural theory, Woodcock et al.'s (2012) use of person-thing orientation, and McLoughlin's (2005) creation and use of the idea of "spotlighting." These articles represent potentially significant theoretical contributions to the EER literature, but seem to have not influenced theoretical frameworks in subsequent *JEE* articles published through 2012.

Taking our cue from engineering education researchers (Jones, Paretti, Hein, & Knott, 2010; Matusovich, Streveler, & Miller, 2010) as well as other researchers (Eccles & Wigfield, 1995) who identified a strong similarity between self-efficacy and expectancy-value theories, we considered these theories together. In fact, all 13 articles use self-efficacy theory, implicitly or explicitly, but one article (Jones et al., 2010) also use expectancy-value theory and uses self-efficacy as an expectancy-related construct.

Hall and Sandler (1982) introduced chilly climate theory – a metaphor to characterize the friendliness or welcome, or lack thereof, toward minorities – to explain minorities' decision to engage in or leave such environments (Beddoes & Pawley, 2013).

We followed Beddoes and Borrego's (2011) definition of liberal feminist frameworks, and their categorization of articles as such when authors emphasize making conditions the same between men and women. Like the articles that use a pipeline framework, those that used liberal feminist frames also tend to do so implicitly, a feature Beddoes and Borrego also noted in studies they examined. However, they identified a larger number of studies framed by liberal feminism than we did. We accounted for this difference by our primary emphasis on general (rather than feminist *per se*) theoretical frameworks; in other words, we categorized the theoretical frame that informs the authors' article, while Beddoes and Borrego categorized articles within a framework constructed by different types of feminist theory specifically.

Our analysis suggests, in contrast with our original supposition, that the range of theory used in engineering education research during this time period was fairly broad in that many theories were used, but theoretical use was also fragmented and shallow, with only a small number of theories used by multiple researchers. This claim contrasts slightly with other content analyses: Beddoes and Borrego (2011), Koro-Ljungberg and Douglas (2008), and Streveler and Smith (2006) have noted the overall use of few theoretical frameworks in EER. Our claim is that a variety of gender theories are used, but that those theories do not reappear in again in later *JEE* articles in the body of articles we studied.

Methods

We characterized a variety of types of methods employed in both the core and periphery articles: quantitative methods, qualitative methods, mixed methods, experiments, instruments, reviews, content analyses, and argument-based methods. These are not entirely parallel categories; the relationships are described below.

We defined quantitative methods as those that rely on numerical data for their analysis, whereas qualitative methods rely on interviews or other text-based data. Experiments were broken out separately from quantitative methods because they use either traditional randomized trials or use quasi-experimental forms with a minimum requirement of some intervention being applied to one group and a comparison group that did not experience the treatment (matched studies are included here). Quasi-experiments are included in the experiment category in light of the ethical and practical limits of conducting randomized trials for some topics in educational research (Light, Singer, & Willett, 1990; Olds, Moskal, & Miller, 2005).

A mixed or multi-method article contains both quantitative and qualitative data, with the requirement that the qualitative component involves the deductive or inductive application or development of themes or categories for analysis. Borrego et al. (2009) argued that such quantification of qualitative data (which still involves qualitative data collection and development of themes) is on the extreme edge of mixed methods. In our study, we only classified an article as having a quantitative component if it presents data that involves more than counts (also including percentages, descriptive statistics, and chi-square tests) of categories. Instrument articles involve the testing and construction of some measurement instrument, such as a survey. Review articles and argument articles either review past research or make an argument based on past research or theory, respectively. For example, since Borrego and Bernhard (2011) provide an overview of major facets of EER and summarized literature, we classified it as a review. Because Adams et al. (2011) examine EER from a series of different lenses to advocate for more diverse formulation of problems in EER, we classified it as an argument article due to its advocacy stance. Similarly, a content analysis article also uses past research as source material, or data; however, in contrast to arguments or reviews, content analyses develop explicit categories or themes by which prior published research is sorted, such as in this study. We differentiated content analyses from systemic reviews as described by Borrego, Foster, and Froyd (2015) in that systemic reviews seem to focus on the results of selected research; content analysis is a more general method that can be applied to any text and, therefore, can categorize the structure of published research, as we use it here.

As Table 3 shows, quantitative methods dominated the core articles, while the periphery articles had greater diversity of methods. Forty-five percent of articles in the periphery and 55% of articles in the core rely on numerical methods only (quantitative articles plus experiments). In comparison, 20% of the core and 17% of the periphery use some kind of qualitative methods only (qualitative articles plus content analysis). The periphery articles contain larger numbers of argument and review articles than the core; this proportion could be due to the fact that our keyword strategy for selecting articles was sensitive to articles' having long discussions (which occur frequently in argument and review articles) simply by virtue of having more words.

In their article, Beddoes et al. (2009) found qualitative studies slightly more frequently than quantitative studies. Since they looked at a wider selection of journals and proceedings (but analyzed fewer years), this finding may mean the methods used in these diverse publication venues may be less concentrated on quantitative studies than *JEE*. Our contrasting finding helps us see the value in analyzing one journal for this article.

Table 3 Methods

	Core articles (%)	Periphery articles (%)
Quantitative	52	34
Qualitative	18	17
Reviews	3	15
Experiments	3	11
Arguments	2	10
Mixed and multi-method	18	7
Instrument	3	6
Content analysis	2	0

Table 4 Research Setting

	Core articles (%)	Periphery articles (%)
University	83	83
K-12	7	13
Business and industry	5	0
Workshop	2	2
Virtual	2	0
Unclear	2	2

Research Setting

Table 4 gives the research settings of the articles. University settings are the vast majority of both core and periphery articles, followed distantly by K-12 settings.

Theory from sociology recognizes that the domains of social life are greatly intertwined and that gender, as a macrosociological (Shaw & Lee, 2009) concept, spans all social settings. So, while universities and K-12 schools may be the focus of most engineering education research, other social settings are also relevant to all actors in engineering education, including to students, instructors, researchers, administrators, families, and passers-by; engineering education research published in *JEE* has scarcely explored gender in these settings through empirical inquiry.

Study Participants

We operationalized participant characteristics through the ideas of participant identity and participant role, both of which can reveal different facets of participants' experiences. We treat them independently. Participant identity refers to oft-ascribed identities given to persons that they carry throughout their life, such as gender (Stryker, 2003); participant role refers to positions or roles, such as student, teacher, or employee (Hage & Powers, 1992) given to persons from an institution such as a school or workplace. To investigate participant identities and roles in the core and periphery, we excluded review articles, argument articles, and content analyses, because they have no participant populations. We therefore had 53 articles in the periphery and 58 in the core for this analysis. Table 5 gives the percentage of articles that focus on each participant identity category.

In the core articles, the two categories 'women and men' and 'women, men, and racial minorities' each compose 40% of the articles; in the periphery, 47% of articles study 'women and men' while 51% study 'women, men, and racial minorities.' No gender-related articles look explicitly and exclusively at men, despite men constituting the majority of people in engineering (National Science Foundation, 2015; Tonso, 2007). Clearly, future research might analyze specific groups in isolation; there could be more studies with only women or any studies with only men.

In the core and the periphery articles, we found little research specifically on women of color and how their experiences might differ from both White women and men of color. Beddoes and Borrego (2011) and Beddoes et al. (2009) also noted this lack of research.

Tables 6 and 7 summarize the percentage of articles focusing on single or multiple participant roles. The majority of core and periphery articles study undergraduate students. This is not surprising considering that most researchers in engineering education are academics and have access to undergraduate students. Nevertheless, the emphasis on analyzing the experiences of undergraduate students can open only one window onto the experiences of women or men in engineering. The experiences of men and women in engineering contexts and careers – from professors to administrators to engineering professionals to K-12 teachers to people operating outside these roles in informal learning contexts – all merit additional study; this final category

Table 5 Participant Identities

	Core articles (%)	Periphery articles (%)
Women and men	40	47
Women, men, and racial minorities	40	51
Women only	13	0
Women and racial minorities	9	0
Racial minorities only	0	2

Table 6 Single Participant Role

	Core articles (%) ($n = 51$)	Periphery articles (%) ($n = 45$)
Undergraduate student only	84	52
K-12 students only	4	11
Industry only	4	0
K-12 teacher only	4	0
Faculty only	2	7
Graduate student only	2	0
Alumni only	0	0
University administrator only	0	0

Table 7 Multiple Participant Roles

	Core articles (%) ($n = 7$)	Periphery articles (%) ($n = 9$)
Undergraduate student	71	78
Faculty	57	44
Industry	43	33
Alumni	29	0
University administrator	14	11
K-12 student	0	33
K-12 teacher	0	22
Graduate student	0	11

(which includes, for example, the study of how people learn in museums, online extracurricular learning, games, everyday learning from books) was entirely absent from the articles examined from *JEE*.

Author Affiliations and Collaborations

We grouped authors into categories based on the organizational affiliation that appeared in their articles. We did this as a proxy for their area of disciplinary research expertise because of the developing nature of the EER field (Borrego & Bernhard, 2011): many researchers in this area may hold a terminal degree in a discipline or field other than engineering. We used the *Digital Commons Three-Tiered Taxonomy of Academic Disciplines* (http://digitalcommons.bepress.com/reference/9/) to group researchers' organizational affiliations into disciplinary fields such as engineering, education, or physical sciences. This taxonomy synthesizes other existing taxonomies, including those by the National Academies (2006) and National Center for Educational Statistics (2010); it provides a comprehensive system which allowed for grouping across the organizational affiliations of *JEE* contributors. Contributors without faculty positions were grouped into three categories: industry for contributors whose primary affiliation was a business; university staff for contributors who were part of a university but were not faculty members; and research centers for contributors who were part of academic interdisciplinary or governmental research centers (e.g., the Center for Engineering Learning and Teaching at the University of Washington). For researchers who had multiple academic departmental affiliations, we used only the first affiliation they listed to avoid double counting.

Table 8 lists individual author organizational affiliations. In the core articles, the most frequent contributors are engineering-affiliated researchers, with social science and education researchers contributing the second and third most, respectively. Combined, these latter two nonengineering fields contribute about the same as engineering itself. In contrast, the majority of contributors in the periphery articles were engineering researchers, with social science and education researchers contributing fewer articles. Results from Beddoes et al. (2009) resembled these; however, they did not report the numbers for each category, so a complete comparison is not possible.

In addition to looking at aggregates of individual authors within fields, we also surveyed co-authorship patterns, which created many types of pairings. We created aggregate categories to explore our primary interest of whether engineering researchers were partnering with social scientists or education researchers, irrespective of whether others were involved.

Table 8 Author Organizational Affiliation

	Core articles (%)	Periphery articles (%)
Engineering faculty	34	51
Social science faculty	17	7
Education faculty	16	10
University staff	9	8
Research center	8	10
Physical sciences faculty	7	6
Industry	4	5
Art faculty	2	2
Business faculty	2	1
Life sciences and medicine faculty	1	1

Our three primary categories are engineering, social science/education, and other. We believed that authors affiliated with engineering have a deeper stake in the research than any other group, and hence warranted their own category, while social science and education researchers have the most useful potential to contribute to the research. We combined social science and education categories for two reasons. First, the disciplines share methodological and theoretical similarities (Green, 2010). Second, our focus was on whether engineering-affiliated researchers were connecting with gender theory produced outside of engineering, and less on which sets of fields contributed more. The category of 'other' includes all articles that had only authors from outside both engineering and the social sciences/education, such as the physical sciences. We simplified the totals by looking at the presence or absence of engineering or social scientist/education researchers, not the balance of author teams; this again was due to our interest in the presence of connections to gender theory outside of engineering.

Table 9 summarizes the distribution of authors by aggregated category (identified in Figure 1) for core or periphery articles. Area A contains collaborations where there are engineering and social science/education researchers, but no one else. Area B contains collaborations with engineering researchers and potentially other researchers, but no social science/education researchers. Area C contains collaborations with social science/education researchers and potentially other researchers, but no engineering researchers. Area D contains collaborations with only other researchers.

Table 8 shows that 51% of authors of periphery articles were affiliated with engineering. Table 9 suggests there are fewer co-authorship instances between social science/education researchers and engineers (23%) in periphery articles than for core

Table 9 Co-Author Collaborations

Area	Affiliation	Core articles (%)	Periphery articles (%)
A	Engineering, social science/ education, and possibly others	37	23
B	Engineering and possibly others	27	61
C	Social science/education and possibly others	21	10
D	Other only	15	6

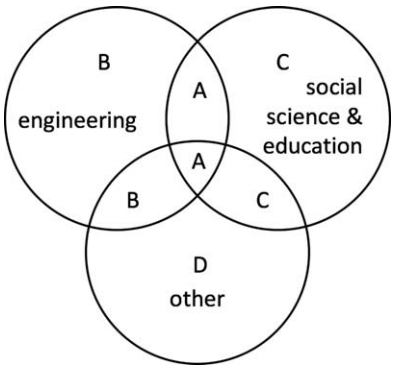

Figure 1 Areas of potential author collaboration.

articles (which exhibited the reverse), with moderately more articles as the product of cross-collaborations (37%) and fewer with engineering authors only (27%). This pattern highlights the more prevalent role social science/education researchers have in core articles as well as the higher rate of cross-disciplinary research between engineering and social scientists/education researchers.

Both multidisciplinary research and interdisciplinary research are forms of cross-disciplinary work. Interdisciplinary research is where theories, methods, or other elements of research are deeply integrated (Klein, 2010), where theories and methods from different areas are combined to create something new. Multidisciplinary research is more loosely integrated and sometimes results from authors' contributing their individual areas of expertise combined into an article. We believe these results show more multidisciplinary than interdisciplinary work. Overall, few methods, research subjects, or recurring theories were brought into or deeply integrated with engineering research; this limited integration leaves the collaborations less deep and hence only multidisciplinary.

Discussion

A majority of the core and periphery articles investigated one type of research setting (universities) and study population role (undergraduate students); almost half the core articles used pipeline theory to frame their research questions and design; and over half of the core articles used quantitative methods only (although there is more diversity of method in the periphery articles).

No core or periphery articles studied men only (although some core articles studied women only). The majority of periphery articles study 'women, men, and racial minorities', so they consider gender and race, but usually not intersectionally. Discussions of intersectionality theory (Collins, 2009; Crenshaw, 1989; hooks, 2000) have revolutionized cultural studies. A key argument of intersectionality is that gender and race must be understood together because understanding the experiences of, say, Black women goes beyond understanding those of White women plus understanding those of Black men. (We note that if this logical algebra held, we could ostensibly simultaneously and directly learn about the experiences of White men from the same two groups – an unconvincing proposition.) Intersectionality would also push researchers to investigate how the ruling relations (Smith, 2005) of an institution are organized to make the experiences of women of color invisible. One notable article in the body of articles we analyzed as incorporating intersectionality is Foor et al.'s (2007) article exploring the experiences of a single participant (who identified as a female, racial minority, first-generation college student from a working class background); this article served as a model to other researchers (Borrego et al., 2009; Paretti, 2008).

Although social and educational scientists significantly contributed to the articles we analyzed, the theories and practices from those disciplines appeared to be systematically underused. This underuse appeared throughout our results in the heavy focus on students and quantitative methods in the core articles; a limited emphasis on women and men in other engineering roles, such as faculty or professionals; a less-refined framing of subjects' identities or separation of identities for in-depth analysis; and a heavy focus on the college settings, with insufficient attention to other social settings that still may be highly interconnected with formal as well as informal (National Research Council, 2009) educational settings.

One possible reason for the limited crossover of theories is that the integration of engineering and social science/educational work itself may be difficult, as discussed below. Our co-authorship analysis illuminates this issue: the analysis shows that cross-disciplinary work

occurs frequently in the core articles (37% of the articles; the largest group) and with moderate frequency in the periphery articles (22% of the articles; the second largest group). We agree with Tonso's (2008) call for more collaborations between social scientists and engineers as a means to better conceptualize gender within the context of engineering. However, in our analysis we found evidence of more multidisciplinary research on gender than interdisciplinary research. Future deep integration of method, theory, context, and experience across diverse fields of interdisciplinary research has the potential to expand the investigation of research questions related to gender.

The specifics of deep integration related to EER have yet to be identified. Past research on cross-disciplinary work within EER has tended to focus on interdisciplinary research processes (Borrego & Newswander, 2008; Mills, Gill, Sharp, & Franzway, 2011) or the experiences of individuals in cross-disciplinary research (Borrego & Creamer, 2007). Analyses of interdisciplinary research rarely emphasize integration attributes; scientometric measures, such as citation patterns, typically drive analyses of integration (Abramo, D'Angelo, & Di Costa, 2012; Wagner et al., 2011), not what makes an article's approach well integrated. However, Huutoniemi et al. (2010) offered a promising exception. They created, then operationalized for empirical work, a conceptual framework on integration based on three measures of interdisciplinarity: scope of interdisciplinarity, that is, how similar or different contributing fields are; type of interdisciplinarity, including multiple types of multidisciplinary (not integrated) and interdisciplinary (e.g., theoretically integrated) research; and goals of interdisciplinary work, including an orientation toward knowledge generation, goals beyond research, and combinations of these. We believe applying their framework to EER would better illuminate questions related to gender in engineering education. In light of the underuse of gender theories from outside of EER, it may be that the widely identified difficulties of interdisciplinary work (outlined in Borrego, 2007a; Mills et al., 2011; Strober, 2010) are hindering the integration of more diverse theoretical views and methods.

Apart from the inherent difficulties of interdisciplinary work, we see two additional difficulties specific to engineering. First, the epistemological views of engineering and the social sciences and education fields – that is, how they view knowledge and what kinds of assumptions they make about it – differ greatly: engineering is primarily focused on objects as the source of its disciplinary knowledge (Biglan, 1973; Vincenti, 1990), whereas the social sciences emphasize foundational knowledge (Biglan, 1973). Engineering is also considered high consensus – that is, its methods, theories, and techniques rarely incur debate over appropriateness (Biglan, 1973; Borrego, 2007a), whereas the social sciences are considered low consensus (Abbott, 2001). Furthermore, engineering is applied both in its application-derived knowledge and its applied foundational knowledge (Gainsburg, Rodriguez-Lluesma, & Bailey, 2010; Godfrey & Parker, 2010; Vincenti, 1990), whereas the social sciences emphasize people and their interactions (Biglan, 1973). These differences between disciplines mean there may be fundamental disagreements within interdisciplinary research teams as to the value of certain forms of knowledge, claims, or subjects. If there are, such research must bridge the epistemological distance between disciplines; doing so may require much more discussion, debate, and negotiation (and, therefore, time) than that of collaborations between more similar fields (Mills et al., 2011; Strober, 2010).

The second difficulty is that gender theories and research designs researchers may find outside EER may be harder to incorporate into EER if journal editors and peer reviewers are unfamiliar with them (Borrego, 2007b) or are otherwise unwilling to accept them as valid frameworks and designs relevant to EER. Beddoes (2012) found that some feminist researchers did not even try to publish their work in general EER journals such as *JEE* because they

felt editors and reviewers would not recognize it as meaningful research. While we only examined published articles that appeared in *JEE*, the fact that only a few articles in our analysis explored gender through a feminist lens suggests that most researchers using these frameworks are publishing their work elsewhere.

Future research should explore more deeply how these difficulties manifest themselves, and the degree (Miller & Mansilla, 2004) or type (Huutoniemi et al., 2010; Klein, 2010) of interdisciplinary work that results in spite of them. This future work should help the engineering education community be more aware about the types of research of which it is largely ignorant, perhaps even intolerant.

Conclusions

This article has shown that research published in *JEE* during 1998–2012 used only a small number of rationales and theories frequently to understand gender in engineering education and only studied a few types of participants' roles in only a few types of research settings.

Our analysis found that core articles had more social scientists and education researchers as contributors and more frequent cross-disciplinary collaboration than periphery articles. In spite of the fact that social scientists and educational researchers contributed to 58% of the core articles, and 33% of the periphery articles, both types of articles lack diversity in their structures. This lack of diversity is shown by a frequent use of the pipeline theoretical framework, quantitative methods, university settings, and undergraduate students as study participants, and by infrequent consideration of intersectionality theory or of gender as something other than a binary demographic variable. Other ways that gender in engineering education could be studied include, for example, assessing how engineering culture in the field or in the classroom is gendered; how engineering students, instructors, industry professionals perform, express, or police gender; how gender is made manifest in engineering language or through written or oral discourse; how technical content is gendered in different ways (including looking at gendered examples in homework, textbooks, museum exhibits, television programs, or computer games); queering gender by problematizing notions of gender as binary, fixed over time, and with clear boundaries; exploring how the gender expressions of LGBTQ+ people in engineering or engineering education are supported or disciplined by others; or analyzing how gender bias is built into engineering educational policy or engineering institutional structure.

It is important to note, however, that we are not critiquing the quality or focus of individual pieces of research we examined. Instead, we think that the body of research published in *JEE* only explored a small fraction of the potential questions that could be investigated to understand women's persisting underrepresentation. This relative homogeneity could have two risky consequences for EER. First, researchers who want to add to the literature on gender and engineering education might try to match the design of their work to that already published there, thereby adding only incremental rather than transformative findings to the research space. Second, upon seeing the lack of diversity, researchers might conclude work drawing on different theoretical traditions is inappropriate for EER, or that *JEE* will not publish research on other such traditions (Beddoes & Borrego, 2011). Both possible outcomes would keep research from developing in new directions; breaking this potential cycle requires both identifying the pattern and then actively working against it.

In addition, readers of *JEE* need to be aware of the narrow range of gender-related research published there. Readers need to know that, at least in the years 1998–2012, *JEE* primarily

published gender-related research that largely conformed to engineers' existing epistemological views. Readers, many of whom devote most of their time to practicing rather than researching engineering education, may not know there is research that can provide them new ways of thinking about women's underrepresentation (or men's overrepresentation) in engineering education. While research using a wider range of theory on gender to investigate engineering education may be published in other journals (such as the *Journal of Women and Minorities in Science and Engineering*), if it is not cited in *JEE*, this varied research is having little influence on EER. Researchers must make these connections to gender research outside EER for the *JEE* readership.

We believe a diversity argument applies to gender research published in *JEE* as well as it does to engineering educational teaching and learning contexts. *JEE* needs a diverse gender research ecosystem. Specifically, we want thoughtful analyses of male engineers and gender-nonconforming engineers as gendered subjects and that conceptualize gender as nonbinary. We want more studies exploring gender using as participants people working in engineering workplaces, faculty and staff working in engineering in universities, people working in and studying engineering in preschool and K-12 contexts, and people encountering engineering in informal learning contexts. We want more studies in *JEE* to incorporate intersectionality in their analyses and to consider gender and race together (rather than independently), along with other identity characteristics such as class, sexuality, ability, and citizenship. We want engineering education researchers to generate more theory about gender in engineering education, but also theory that helps us understand how gender functions in contemporary American society more broadly. EER need not only use gender theories developed in other disciplines; research done on engineering and engineering education can help show how gender functions as a social force. We want researchers to move beyond justifying studying gender inequity due to the fact of women's underrepresentation, because this rationale suggests that gender inequity will disappear when the numbers of men and women in engineering in the United States are more proportional to the general population. But one can see that proportionality does not destroy patriarchy by observing the persisting gender inequity in the general population, despite proportionality (Connell, 2009).

We can diversify gender research through developing stronger collaborations with diverse others (such as researchers in disciplines that have developed more comprehensive or epistemologically different theories about gender and about what constitutes engineering than we have identified here in *JEE*) and through diversifying the settings in which we conduct our research. Overall, a broader range of research should deepen our understanding of the intersection of gender and engineering and allow for creation of better practices to address underrepresentation, marginalization, discrimination, gendered and raced power relations, and gendered and raced institutional structures. A more aware EER that better builds on the theoretical contributions of other disciplines would better inform educational practice (Jamieson & Lohman, 2009) than it currently can.

We believe that creating a more useful and productive field of gender EER requires comprehensive and intentional efforts on the part of *JEE* editors, reviewers, authors, and readers. Authors should seek more theories from outside EER to inform research with fresh theoretical insights. They should collaborate with more social scientists and education researchers whose theories may question EER biases, and they should increasingly recommend expert reviewers who are not regularly reviewing for EER journals. Journal editors should also solicit scholars from outside EER with gender theory expertise as reviewers to suggest to authors new theories to use, and could revise manuscript assessment criteria to prompt reviewers to reflect on authors'

use of gender theory, including how authors report their study participants' demographics. Reviewers should more intentionally consider EER's epistemological biases as they assess the theoretical foundations of submitted manuscripts. And readers of *JEE* should also seek EER-related materials about gender outside of *JEE*, in order to broaden their theoretical vocabularies.

We acknowledge the limitations of our analysis. We analyzed only *JEE*, and only from 1998 to 2012, and used this body of articles as a broad indicator about EER publications. We believe that *JEE*, the *International Journal of Engineering Education*, the *European Journal of Engineering Education*, the *Annals of Engineering Education*, and the *Australasian Journal of Engineering Education* have very different publication cultures, as Wankat et al.'s (2014) analysis comparing *JEE* and *EJEE* suggested. As the flagship American EER publication, *JEE* merits some focus, but we acknowledge that future analysis of other journals will be necessary to get a more reliable and generalizable interpretation of gender in EER. We strongly encourage any researchers coming after us to broaden their focus to include other EER publications. In addition, we did not independently verify authors' biographies and affiliations through institutional websites, relying only on data supplied in the journal. Finally, augmenting a content analysis with a bibliometric analysis (such as a citation analysis) could help sharpen or verify these findings. We leave following these and other directions to future researchers.

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References

Abbott, A. (2001). *Chaos of disciplines*. Chicago, IL: University of Chicago Press.

Abramo, G., D'Angelo, C. A., & Di Costa, F. (2012). Identifying interdisciplinarity through the disciplinary classification of coauthors of scientific publications. *Journal of the American Society for Information Science and Technology*, *63*(11), 2206–2222. http://dx.doi.org/10.1002/asi.22647

Adams, R. S., Dias de Figueiredo, A., Evangelou, D., English, L. D., Mousoulides, N., Pawley, A. L., … Wilson, D. (2011). Multiple perspectives for engaging future engineers. *Journal of Engineering Education*, *100*(1), 48–88. http://dx.doi.org/10.1002/j.2168-9830.2011.tb00004.x

Beddoes, K. (2011). *Problematizations of women's underrepresentation: Comparing educator interviews with the literature*. Frontiers in Education Conference, Rapid City, South Dakota. http://dx.doi.org/10.1109/FIE.2011.6143035

Beddoes, K. D. (2012). Feminist scholarship in engineering education: Challenges and tensions. *Engineering Studies*, *4*(3), 205–232. http://dx.doi.org/10.1080/19378629.2012.693932

Beddoes, K., & Borrego, M. (2011). Feminist theory in three engineering education journals. *Journal of Engineering Education*, *100*(2), 281–303. http://dx.doi.org/10.1002/j.2168-9830.2011.tb00014.x

Beddoes, K., Borrego, M., & Jesiek, B. K. (2009). *Mapping international perspectives on gender in engineering education research*. ASEE/IEEE Frontiers in Education Conference, San Antonio, TX. http://dx.doi.org/10.1109/FIE.2009.5350766

Beddoes, K., & Pawley, A. L. (2013). "Different people have different priorities": Work–family balance, gender, and the discourse of choice. *Studies in Higher Education*, *39*(9), 1573–1585. http://dx.doi.org/10.1080/03075079.2013.801432

Berg, B. L. (2007). *Qualitative research methods for the social sciences* (6th ed.). New York, NY: Pearson Education. http://dc.etsu.edu/assets/taxonomy.pdf

Berryman, S. E. (1983). *Who will do science? Minority and female attainment of science and mathematics degrees: Trends and causes*. New York, NY: Rockefeller Foundation.

Biglan, A. (1973). The characteristics of subject matter in different academic areas. *Journal of Applied Psychology*, *57*(3), 195–203. http://dx.doi.org/10.1037/h0034701

Borrego, M. (2007a). Conceptual difficulties experienced by trained engineers learning educational research methods. *Journal of Engineering Education*, *96*(2), 91. http://dx.doi.org/10.1002/j.2168-9830.2007.tb00920.x

Borrego, M. (2007b). Development of engineering education as a rigorous discipline: A study of the publication patterns of four coalitions. *Journal of Engineering Education*, *96*(1), 5–18. http:/dx.doi.org/10.1002/j.2168-9830.2007.tb00911.x

Borrego, M., & Bernhard, J. (2011). The emergence of engineering education research as an internationally connected field of inquiry. *Journal of Engineering Education*, *100*(1), 14–47. http://dx.doi.org/10.1002/j.2168-9830.2011.tb00003.x

Borrego, M., & Creamer, E. G. (2007). Gender and disciplinary differences in experience with interdisciplinary collaboration. *Journal of Women and Minorities in Science and Engineering*, *13*(4). http://dx.doi.org/10.1615/JWomenMinorScienEng.v13.i4.30

Borrego, M., Douglas, E. P., & Amelink, C. T. (2009). Quantitative, qualitative, and mixed research methods in engineering education. *Journal of Engineering Education*, *98*(1), 53–66. http://dx.doi.org/10.1002/j.2168-9830.2009.tb01005.x

Borrego, M., Foster, M. J., & Froyd, J. (2015) What is the state of the art of systemic review in engineering education? *Journal of Engineering Education*, *104*(2), 212–242. http://dx.doi.org/10.1002/jee.20069

Borrego, M., & Newswander, L. K. (2008). Characteristics of successful cross-disciplinary engineering education collaborations. *Journal of Engineering Education*, *97*(2), 123–134. http://dx.doi.org/10.1002/j.2168-9830.2008.tb00962.x

Collins, P. H. (2009). *Black feminist thought*. New York, NY: Routledge.

Connell, R. (2009). *Gender*. London: Polity Press.

Crenshaw, K. (1989). Demarginalizing the intersection of race and sex: A Black feminist critique of antidiscrimination doctrine, feminist theory and antiracist politics. *University of Chicago Legal Forum*, *1989*(1), 139–168. http://chicagounbound.uchicago.edu/uclf/vol1989/iss1/8

Douglas, E. P., Koro-Ljungberg, M., & Borrego, M. (2010). Challenges and promises of overcoming epistemological and methodological partiality: Advancing engineering education through acceptance of diverse ways of knowing. *European Journal of Engineering Education*, *35*(3), 247–257. http://dx.doi.org/10.1080/03043791003703177

Eccles, J.S., & Wigfield, A. (1995). In the mind of the actor: The structure of adolescents' achievement task values and expectancy-related beliefs. *Personality and Social Psychology Bulletin*, *21*(3), 215–225. http://dx.doi.org/10.1177/0146167295213003

Foor, C. E., Walden, S. E., & Trytten, D. A. (2007). "I wish that I belonged more in this whole engineering group": Achieving individual diversity. *Journal of Engineering Education*, *96*(2), 103–115. http://dx.doi.org/10.1002/j.2168-9830.2007.tb00921.x

Gainsburg, J., Rodriguez-Lluesma, C., & Bailey, D. E. (2010). A "knowledge profile" of an engineering occupation: Temporal patterns in the use of engineering knowledge. *Engineering Studies*, *2*(3), 197–219. http://dx.doi.org/10.1080/19378629.2010.519773

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method.*. New York, NY: Routledge.

Godfrey, E., & Parker, L. (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education*, *99*(1), 5–22. http://dx.doi.org/10.1002/j.2168-9830.2010.tb01038.x

Green, B. (2010). Knowledge, the future, and education(al) research: A new-millennial challenge. *Australian Educational Researcher*, *37*(4), 43–62.http://dx.doi.org/10.1007/BF03216936

Hage, J., & Powers, C. H. (1992). *Post-industrial lives: Roles and relationships in the 21st century.* Newbury Park, CA: Sage.

Hall, R. M., & Sandler, B. R. (1982). *The classroom climate: A chilly one for women?* Washington, DC: Project on the Status and Education of Women..

Hill, C., Corbett, C., & St. Rose, A. (2010). *Why so few?: Women in science, technology, engineering and mathematics*. Washington DC: AAUW. https://www.aauw.org/files/2013/02/Why-So-Few-Women-in-Science-Technology-Engineering-and-Mathematics.pdf

Hood, W. W., & Wilson, C. S. (2001). The literature of bibliometrics, scientometrics, and informetrics. *Scientometrics*, *52*(2), 291–314.http://dx.doi.org/10.1023/A:1017919924342

hooks, b. (2000). *Feminist theory: From center to margins* (2nd ed.). Cambridge, MA: South End Press.

Hubbard, D. (2010). *An analysis of ASEE-ELD conference proceedings: 2000-2009*. ASEE Annual Conference, Louisville, KY. https://peer.asee.org/16290

Huutoniemi, K., Klein, J. T., Bruun, H., & Hukkinen, J. (2010). Analyzing interdisciplinarity: Typology and indicators. *Research Policy*, *39*(1), 79–88. http://dx.doi.org/10.1016/j.respol.2009.09.011

Ihsen, S., Jesiek, B., Kammasch, G., & Beddoes, K. (2010). *Diversity of didactical approaches to foster diversity of engineers*. European Society for Engineering Education (SEFI) Annual Conference, Trnava, Slovakia. http://www.sefi.be/wp-content/papers2010/abstracts/307.pdf

Jamieson, L. H., & Lohman, J. R. (2009). *Creating a culture for scholarly and systematic innovation in engineering education*. http://www.asee.org/about-us/the-organization/advisory-committees/CCSSIE/CCSSIEE_Phase1Report_June2009.pdf

Jesiek, B. K., and Beddoes, K. (2012). *Diversity in Engineering (DinE) Bibliography* [Online document]. http://www.inesweb.org/dine/

Jesiek, B. K., & Beddoes, K. (2013). Diversity in engineering (DinE) bibliography research brief. *Engineering Studies*, *5*(1), 90–92. http://dx.doi.org/10.1080/19378629.2012.746807

Jones, B. D., Paretti, M. C., Hein, S. F., & Knott, T. W. (2010). An analysis of motivation constructs with first-year engineering students: Relationships among expectancies, values, achievement, and career plans. *Journal of Engineering Education*, *99*(4), 319–336. http://dx.doi.org/10.1002/j.2168-9830.2010.tb01066.x

Jesiek, B. K., Borrego, M., Beddoes, K., Hurtado, M., Rajendran, P., & Sangam, D. (2011). Mapping global trends in engineering education research, 2005–2008. *International Journal of Engineering Education*, *27*(1), 77–90. http://www.ijee.ie/latestissues/Vol27-1/11_Ijee2391ns.pdf

Jesiek, B. K., Newswander, L. K., & Borrego, M. (2009). Engineering education research? Discipline, community, or field? *Journal of Engineering Education*, *98*(1), 39–52. http://dx.doi.org/10.1002/j.2168-9830.2009.tb01004.x

Kanny, M. A., Sax, L. J., & Riggers-Piehl, T. A. (2014). Investigating forty years of STEM research: How explanations for the gender gap have evolved over time. *Journal of Women and Minorities in Science and Engineering*, *20*(2), 127–148. http://dx.doi.org/10.1615/JWomenMinorScienEng.2014007246

Klein, J. T. (2010). The taxonomy of interdisciplinarity. In R. Frodeman et al. (Eds.), *Oxford handbook of interdisciplinarity* (pp. 15–30). Oxford, UK: Oxford University Press.

Koro-Ljungberg, M., & Douglas, E. P. (2008). State of qualitative research in engineering education: Meta-analysis of JEE Articles. *Journal of Engineering Education*, *97*(2), 163–175.http://dx.doi.org/10.1002/j.2168-9830.2008.tb00965.x

Light, R., L., Singer, J. D., & Willett, J. B. (1990). *By design: Planning research on higher education.* Cambridge, MA: Harvard University Press.

Matusovich, H. M., Streveler, R. A., & Miller, R. L. (2010). Why do students choose engineering? A qualitative, longitudinal investivation of students' motivational values. *Journal of Engineering Education*, *99*(4), 289–303. http://dx.doi.org/10.1002/j.2168-9830.2010.tb01064.x

McLoughlin, L. A. (2005). Spotlighting: Emergent gender bias in undergraduate engineering education. *Journal of Engineering Education*, *94*(4), 373–381. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00865.x

Miller, M., & Mansilla, V. B. (2004). *Thinking across perspectives and disciplines*. Paper from the Interdisciplinary Studies Project of Project Zero. http://evergreen.edu/washingtoncenter/docs/resources/millerboix.pdf

Mills, J. E., Gill, J., Sharp, R., & Franzway, S. (2011). Getting it together: Feminist interdisciplinary research on women and engineering. *Women's Studies International Forum*, *34*(1), 13–19. http://dx.doi.org/10.1016/j.wsif.2010.09.014

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine. (2006). Beyond bias and barriers: *Fullfilling the potential of women in academic science and engineering*. http://dx.doi.org/10.17226/11741

National Center for Education Statistics. (2010). *Classification of Instructional Programs* (CIP-2010). https://nces.ed.gov/ipeds/cipcode/resources.aspx?y=55

National Research Council. (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC. http://dx.doi.org/10.17226/12190

National Science Foundation Division of Science Resources Statistics. (2015). *Women, minorities, and persons with disabilities in science and engineering*. Arlington, VA. http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab2-9.pdf; http://www.nsf.gov/statistics/2015/nsf15311/tables/pdf/tab3-1-updated-2016-06.pdf

Olds, B., Moskal, B. M., & Miller, R. L. (2005). Assessment in engineering education: Evolution, approaches and future collaborations. *Journal of Engineering Education*, *94*(1), 13–25. http://dx.doi.org/10.1002/j.2168-9830.2005.tb00826.x

Paretti, M. C. (2008). Teaching communication in capstone design: The role of the instructor in situated learning. *Journal of Engineering Education*, *94*(4), 491–503. http://dx.doi.org.10.1002/j.2168-9830.2008.tb00995.x

Pawley, A. L. (2013). *Learning from small numbers of underrepresented students' stories: Discussing a method to learn about institutional structure through narrative*. ASEE Annual Conference, Atlanta, GA. https://peer.asee.org/19030

Pawley, A. L., & Phillips, C. M. L. (2014). *From the mouths of students: Two illustrations of narrative analysis to understand engineering education's ruling relations as gendered and raced*. ASEE Annual Conference, Indianapolis, IN. https://peer.asee.org/20524

Roberts, C. W. (1997). *Text analysis for the social sciences: Methods for drawing statistical inferences from texts and transcripts*. Mahwah, NJ: Lawrence Erlbaum.

SCImago. (2007). SCImago Journal & Country Rank [Webpage]. http://www.scimagojr.com

Shaw, S. M., & Lee, J. (2009). *Women's voices, feminist visions: Classic and contemporary readings*. New York, NY: McGraw-Hill.

Smith, D. E. (2005). *Institutional ethnography: A sociology for people*. Walnut Creek, CA: AltaMira Press.

Spradley, J. (1980). *Participant observation*. Chicago, IL: Rinehart, Winston.

Streveler, R. A., & Smith, K. A. (2006). Conducting rigorous research in engineering education. *Journal of Engineering Education*, *95*(2), 103–105. http://dx.doi.org/10.1002/j.2168-9830.2006.tb00882.x

Strober, M. (2010). *Interdisciplinary conversations: Challenging habits of thought*. Stanford, CA: Stanford University Press.

Stryker, S. (2003). *Symbolic interactionism: A social structural version* (2nd ed.). Caldwell, NJ: Blackburn Press.

Tonso, K. L. (2007). *On the outskirts of engineering: Learning identity, gender, and power via engineering practice*. Rotterdam, the Netherlands: Sense.

Tonso, K. L. (2008). Knowing a hawk from a handsaw: Interdisciplinarity and STEM education research. In H. Hartman (Ed.), *Integrating the sciences and society: Challenges, practices, and potentials* (pp. 31–50). Emerald Group.

Vincenti, W. G. (1990). *What engineers know and how they know it: Analytical studies from aeronautical history*. Baltimore, MD: John Hopkins Press.

Wagner, C. S., Roessner, J. D., Bobb, K., Klein, J. T., Boyack, K. W., Keyton, J., … Börner, K. (2011). Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature. *Journal of Informetrics*, *5*(1), 14–26. http://dx.doi.org/10.1016/j.joi.2010.06.004

Wankat, P. C. (2004). Analysis of the first ten years of the Journal of Engineering Education. *Journal of Engineering Education*, *93*(1), 13–22. http://dx.doi.org/10.1002/j.2168-9830.2004.tb00784.x

Wankat, P. C., Williams, B., & Neto, P. (2014). Engineering education research in European Journal of Engineering Education and Journal of Engineering Education: Citation and reference discipline analysis. *European Journal of Engineering Education*, *39*(1), 7–17. http://dx.doi.org/10.1080/03043797.2013.867316

Weber, R. P. (1990). *Basic content analysis*. Newbury Park, CA: Sage.

Whitin, K., & Sheppard, S. (2004). Taking stock: An analysis of the publishing record as represented by the Journal of Engineering Education. *Journal of Engineering Educationn*, *93*(1), 5–12. http://dx.doi.org/10.1002/j.2168-9830.2004.tb00783.x

Woodcock, A., Graziano, W. G., Branch, S. E., Ngambeki, I., & Evangelou, D. (2012). Engineering students' beliefs about research: Sex differences, personality, and career plans. *Journal of Engineering Education*, *101*(3), 495–511. http://dx.doi.org/10.1002/j.2168-9830.2012.tb00059.x

Yoder, B. L. (2013). *Engineering by the Numbers*. http://www.asee.org/papers-and-publications/publications/14_11-47.pdf

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