2018 ASEE Annual Conference & Exposition

Paper ID #21352

A Systematic Literature Review on Improving Success of Women Engineering Students in the U.S.

Dr. Pradeep Kashinath Waychal, Western Michigan University

Dr Pradeep Waychal is a visiting professor at the CRICPE of Western Michigan University, a founder trustee of Guruji Education Foundation that provides holistic support to the higher education of underprivileged students, and an academic adviser to many Indian educational institutes. Earlier, Dr Waychal has worked at Patni Computer Systems for 20 years in various positions including the head of innovations, NMIMS as the director Shirpur campus, and at College of Engineering Pune (COEP) as the founder head of the innovation Center.

Dr Waychal earned his Ph D in the area of developing Innovation Competencies in Information System Organizations from IIT Bombay and M Tech in Control Engineering from IIT Delhi. He has presented keynote / invited talks in many high prole international conferences and has published papers in peer-reviewed journals. He / his teams have won awards in Engineering Education, Innovation, Six Sigma, and Knowledge Management at international events. His current research interests are engineering education, software engineering, and developing innovative entrepreneurs and intrapreneurs. He was chosen as one of the five outstanding engineering educators by IUCEE (Indo-universal consortium of engineering education) in 2017.

Dr. Charles Henderson, Western Michigan University

Charles Henderson is a Professor at Western Michigan University (WMU), with a joint appointment between the Physics Department and the WMU Mallinson Institute for Science Education. He is the Director of the Mallinson Institute and co-Founder and co-Director of the WMU Center for Research on Instructional Change in Postsecondary Education (CRICPE). His research program focuses on understanding and promoting instructional change in higher education, with an emphasis on improving undergraduate STEM instruction. Dr. Henderson's work has been supported by over $9M in external grants and has resulted in many publications (see https://sites.google.com/view/chenderson). He is a Fulbright Scholar and a Fellow of the American Physical Society. Dr. Henderson is the senior editor for the journal "Physical Review Physics Education Research" and has served on two National Academy of Sciences Committees: Undergraduate Physics Education Research and Implementation, and Developing Indicators for Undergraduate STEM Education.

Dr. Daniel Collier, Western Michigan University

Daniel (Dan) is an alum of Bradley University, Roosevelt University, and The University of Illinois - Urbana/Champaign - and currently serves as a post-doctoral researcher for the Center for Research on Instructional Change in Postsecondary Education at Western Michigan University. Recently, Dan has been involved with the Broncos FIRST FITW project and has developed ongoing research with stakeholders from Kalamazoo Promise and the Upjohn Institute. One of Dan's most recent articles employed machine learning techniques to model sentiments surrounding the previously announced tuition-free college program Americans College Promise - the article can be found in the Journal of Further and Higher Education. Dan is adept at quantitative and qualitatively methods and is currently finishing up a data scientist certificated fixated on Big Data, Geospatial Data, and Data Visualization.

©American Society for Engineering Education, 2018

A systematic literature review of analysis of success of undergraduate engineering women students in the US

Introduction

Over the past three decades, women in the United States (US) have outpaced men in enrollment and degree obtainment in higher education[1], but not in engineering education[2,3]. Figure 1 provides the percentage engineering bachelor's degrees awarded to female students of all engineering bachelor's degrees awarded in the US from 2006 to 2014. While the earlier downward trend is reversed, the significant underrepresentation of women in engineering remains. The underrepresentation of women creates a lack of diversity in engineering workforce, which hampers development of innovative and customer-centric solutions, and is due to poor recruitment and retention. For this study, we consider retention, six-year graduation, and academic performance as the elements of success of women engineering students, which many researchers have studied. A systematic review of these numerous studies, which analyzes various research findings can help educators and administrators understand and boost the success of women in engineering education. Towards that, this paper systematically reviews and analyzes papers published in the Journal of Engineering Education (JEE) from 1993 through 2016 that claimed to study gender and success in undergraduate engineering programs in the US.

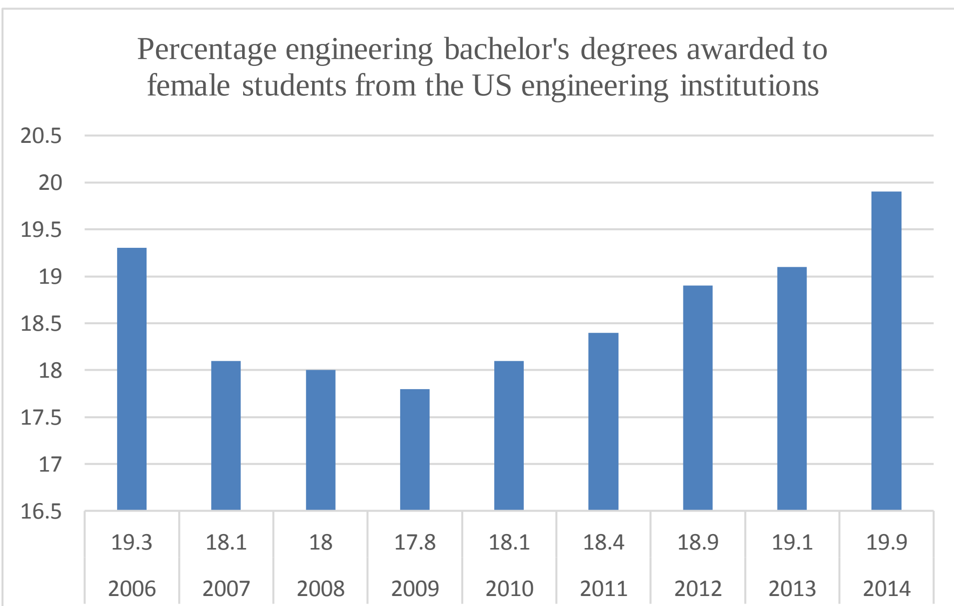

Figure 1: Percentage of engineering bachelor's degrees awarded to female students of all engineering bachelor's degrees from the US engineering institutions (2006-2014)

Process

Like any systematic review, this study organizes, evaluates, and synthesizes literature; identifies patterns, trends, and research gaps; recommends new research areas[4]; and provides comprehensive landscapes based on multiple studies, which can expedite further research in the area[5]. Figure 2 summarizes the review process.

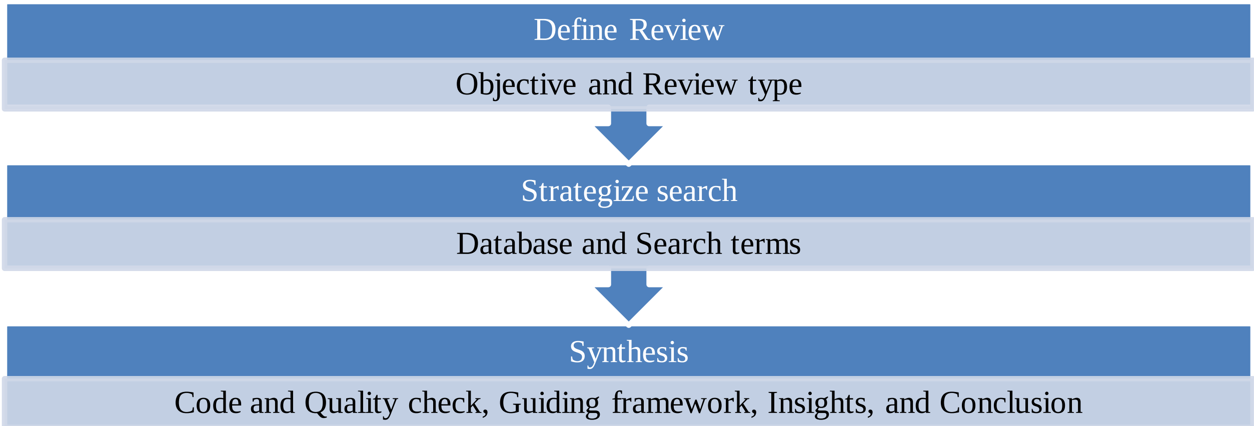

Figure 2: Systematic Review Method

Define Review

Objective

The objective of our study is to systematically review and analyze literature on improving the success of women students in undergraduate engineering in the US.

Review Type

Reviews can be broadly classified as narrative reviews and systematic reviews[4]. This paper undertakes a systematic review, which is characterized by more formalized procedures for searching, selecting, coding, and synthesizing literature[6]. Finfgeld expects systematic reviews to produce a new and integrative interpretation of findings that is more substantive than those resulting from individual investigations[7]. Borrego et al. consider systematic reviews to be a promising approach to advance the field as it synthesizes prior work. The synthesis, they say, can potentially lead to better theoretical foundations, better informed practices, and identification of new research directions[8].

Reviews can also be broadly classified as status quo reviews that present the most current research in a given field of research, or historical reviews that present the development in a given field of research over time[9]. Our review belongs in the historical category as we have included papers from 1993.

Strategize Search

Database

We review papers from ASEE (American Society of Engineering Education)'s Journal of Engineering Education (JEE) (ISSN 2168-9830), a primary publication choice for engineering education researchers, especially in the US[10]. Pawley et al.[11] argue that JEE is the flagship and the most highly ranked journal of the American engineering education researcher community and chose it for their gender research review that identifies dominant themes and patterns in the structure of gender research. JEE is hosted by Wiley and provides an advanced search mechanism; however, we did not find it to be user friendly and used Publish or Perish tool along with Google scholar database.

Search Terms

We searched for papers having at least one term for women underrepresentation and at least one term for success. Table 1 shows the underrepresentation and success terms. We developed an initial set of search terms based on literature review and revised the set based on feedback from experts in the field. The revision resulted in the addition of "student performance", "dropout", and "drop-out" to the list of success terms.

Table 1 - Search Terms. (Selected papers have at least one underrepresentation term and one success term).

Underrepresentation terms	gender OR female OR woman OR women OR underrepresented OR minority OR minorities
Success terms	persistence OR retention OR "student success" OR "students' success" OR attrition OR "student performance" OR dropout OR drop-out

Synthesis

Code and quality check

Our search, using the search terms given in Table 1, yielded 244 papers that were published between 1993 and 2016. Out of those 244 papers, based on abstracts, we found 188 were not relevant i.e. they did not discuss success of women engineering students in the US. We studied the remaining 57 papers and found 40 of them to be relevant. We coded those 40 papers in an excel sheet (Table 2) and in a word document (Table 3). Author 1 proposed structures for these tables, which Author 2 and a research scholar reviewed. Furthermore, influenced by Borrego, et al.[12] and Salleh et al.[13], Author 3 conducted a quality check on the papers, which Author 1 reviewed. Unsurprisingly, with JEE, all papers were found to be of high quality. The authors also sought inputs from in-house researchers and external experts to maximize the quality of the research. Appendix A provides the details of the selected 40 papers.

Table 2: Coding used for top-level information in excel sheet

Author names	How many authors are from engineering departments
Departments of the authors	Method of study (Quantitative or Qualitative)
How many authors from education / other departments	Subject of study (Gender, All underrepresented, intersection such as Hispanic Women)
Universities of the authors	Title
Category (Core[1], Periphery, Review)	Year of publication
Type (Analysis, Analysis + solutions, and Analysis + Solutions with evidence)	Quality ranking (High, Medium, Low)

Table 3: Coding used for detailed information in word document

Title, Authors and Publication year	Solutions presented
Focus and Research questions	Research methods adopted
Data collected /presented	Key conclusions
Frameworks used	Quotes (from other papers)
Analysis	Important references (useful papers referred by the paper)

Analytical Insights

In this section, we present insights based on the papers that we studied. At the outset, we present insights on patterns of papers followed by other insights that are divided in three temporal phases: K12, transition to college, and during college (Figure 3). We have further divided the 'during college' phase in three areas; academic, social, and professional integration based on prior work by Lee and Matusovich[14], who undertook a multi-case study of six programs for under-represented students to develop a model for co-curricular support based on Tinto's institutional departure model. The model included integration at academic, social, professional and university levels. We excluded university integration as we did not find any insights in our review in that category.

[1] The papers with research questions having 'gender success' related terms are classified as core and others are classified as periphery

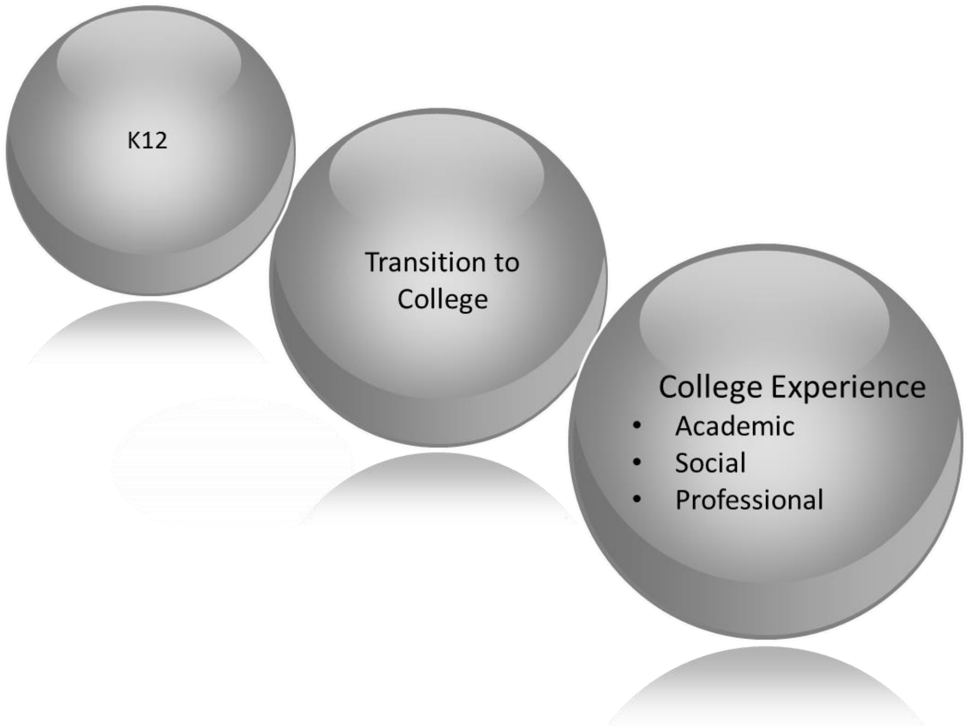

Figure 3 – Categorization of insights in three temporal phases

Patterns of papers

Insight 1: Over time, more advanced quantitative techniques such as hierarchical multiple linear regression, cluster analysis, and survival analysis have become more frequent.

Majority of articles in our review did quantitative analysis such as descriptive analysis[15, 16, 17] or predictive analysis[18, 19, 20, 21,22]. Over time, more advanced quantitative techniques, such as, hierarchical multiple linear regression [20], cluster analysis[23], and survival analysis[24,25] are used.

Insight 2: There is a movement towards higher inclusion of qualitative methodologies

Although more articles used purely quantitative methodologies, our sample suggests a movement, over time, towards qualitative[14,26,27] and mixed methods[28-30]. Figure 4 presents the distribution with three different time periods (1993-2003, 2004-2009, 2010-2016) on the X-axis and percentage of qualitative and mixed papers on the Y-axis. The three periods have around 12 papers each. This, perhaps, highlights the evolution of the JEE journal and the increased interest in qualitative experiences of students. Quite possibly, such evolution has been driven by the establishment of engineering education departments, whose faculty have been authoring more papers.

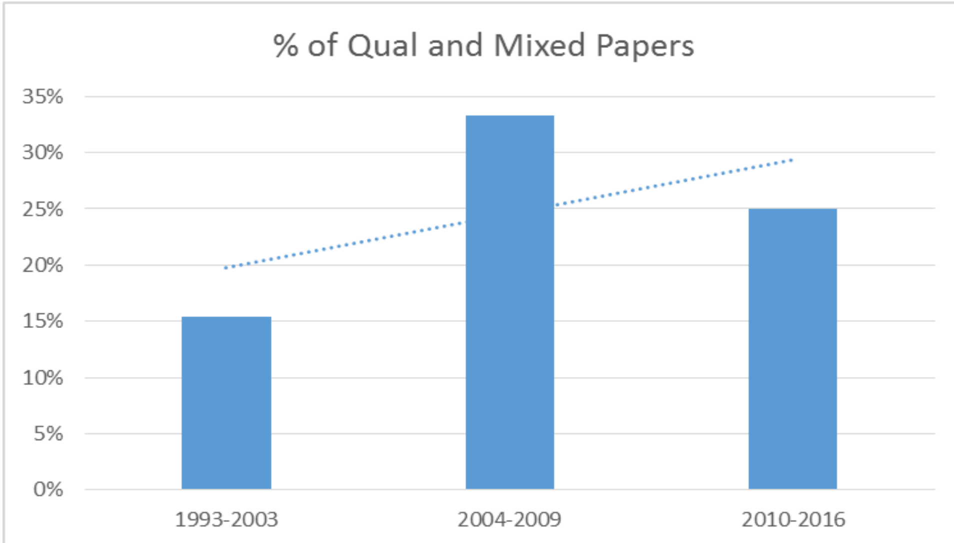

Figure 4: Percentage of qualitative or mixed papers to the total paper that we studied. Each period has around 12 papers.

Insight 3: Engineering education departments' faculty have been writing more articles.

Figure 5 provides the division between authors' affiliations from 1993, and Figure 6 from 2003, when the first paper in this sample appeared from an education department. Some of the earlier papers have not mentioned authors' affiliations, which is indicated by 'information not available' in the figures. It seems that the establishment of engineering education departments may have given a fillip to gender and higher quality research.

Insight 4: There has been an increase of core papers that research specific aspects of women's success

Women's underrepresentation seems to be attracting more attention and the number of papers that have research question(s) that explicitly mention some aspects of gender success has been rising. Figure 7 presents the distribution with three different time periods on the X-axis (1993-2003, 2004-2009, 2010-2016) and percentage of core papers on the Y-axis. The three periods have around the same number of papers.

Insight 5: There is lesser focus on providing solutions than analyzing situation, and much lesser focus on providing solutions with evidences

We were ideally looking for papers that tested solutions in an experimental design (with a control or comparison group) and post-solution success measurements (such as retention). Only two papers[31],[23] came close to this ideal. However, even they fell short of selecting treatment and control groups randomly. The remaining nineteen papers only analyzed some aspects of gender parity and seventeen papers included solutions based on analysis. One was a review paper (Figure 8). The forty papers were written by authors from thirty universities, and Purdue (9) appeared to be the most active followed by Virginia Tech (4) University of Florida (4), NC state (3) and University of Washington (3).

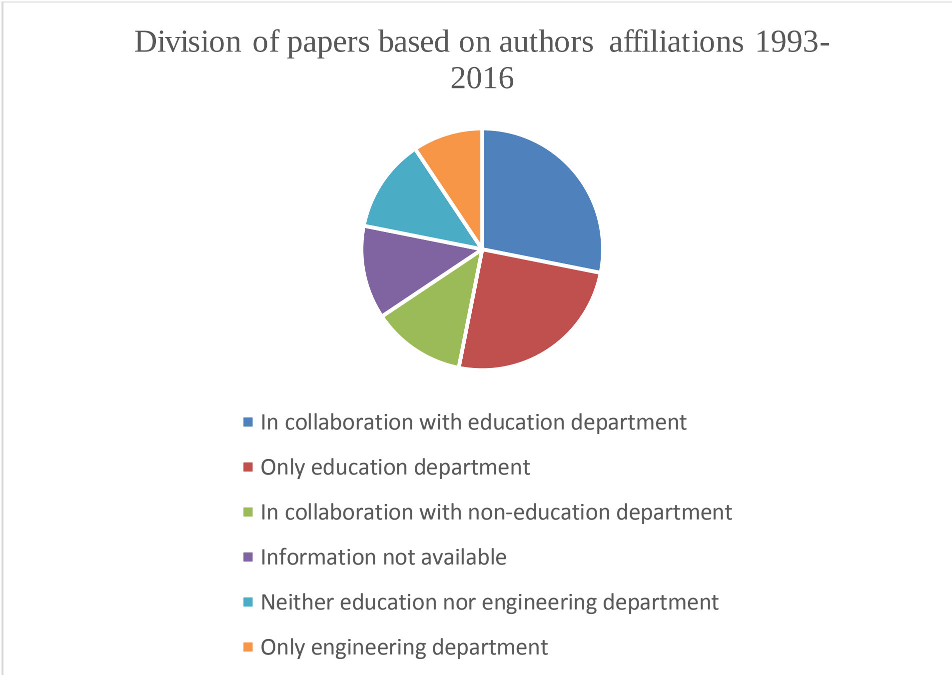

Figure 5: Division of papers based on authors' affiliation (1993-2016)

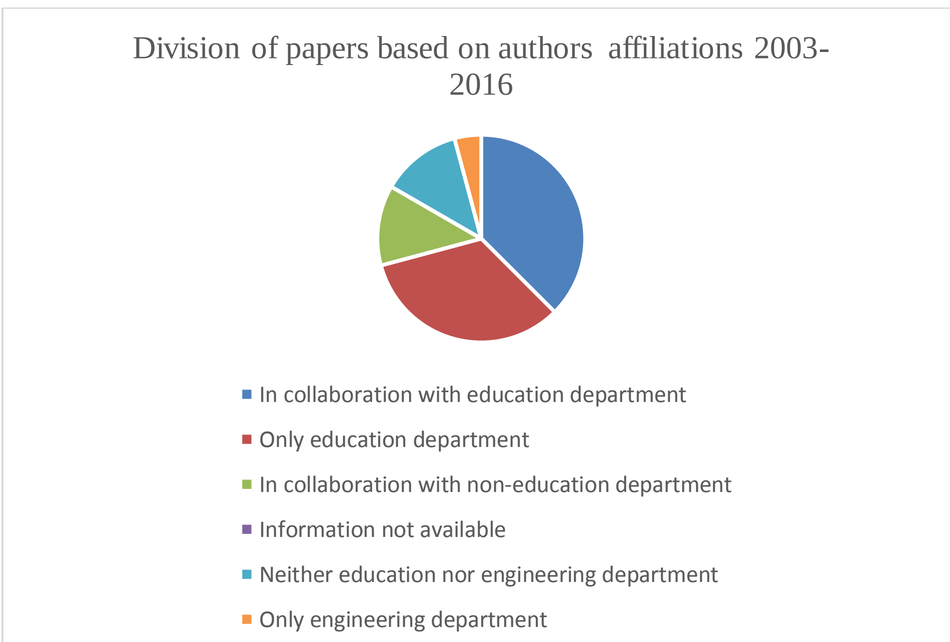

Figure 6: Division of papers based on authors' affiliation (2003-2016)

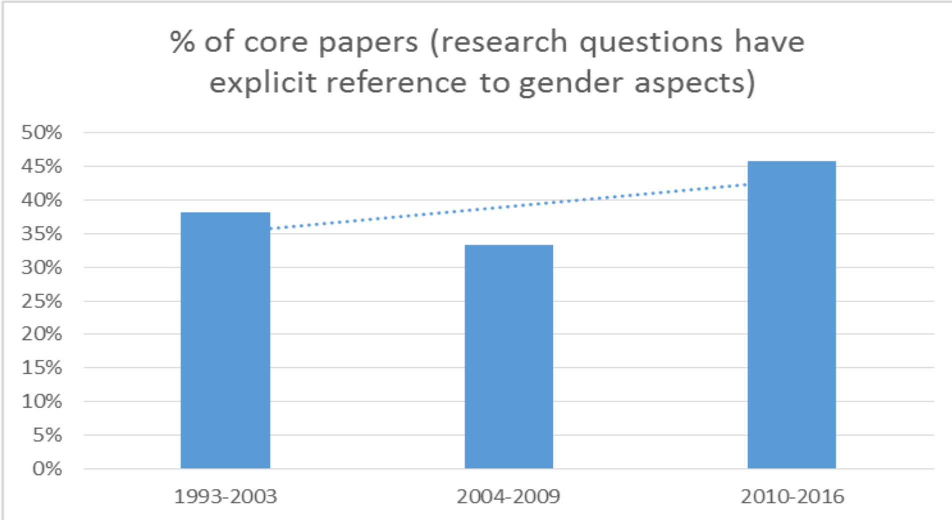

Figure 7: Percentage of core papers over different time periods. Each period has around 12 papers.

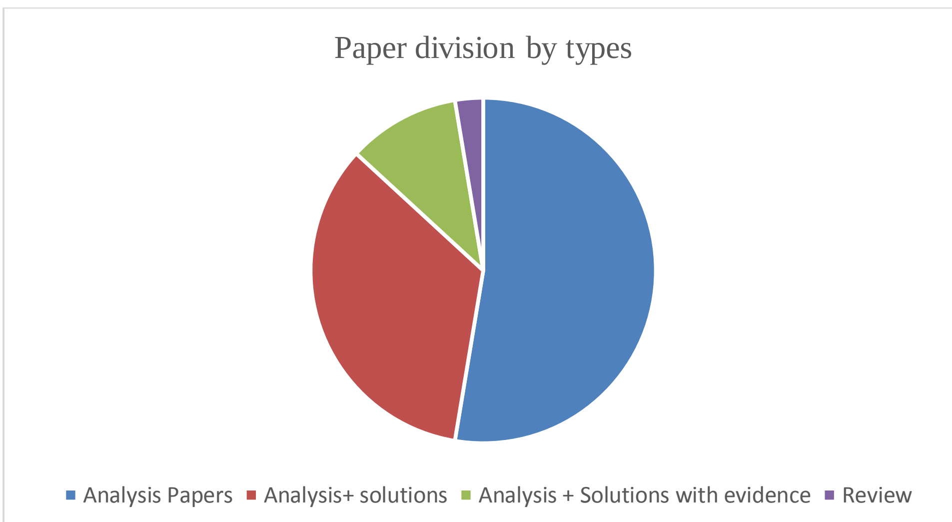

Figure 8: Division of papers by types

K-12

Insight 1: High school performance impacts the success in engineering education and high schools require providing a healthy pipeline of women students

The papers that studied the K-12 phase, illustrated the importance of high school performance and a healthy pipeline of women students. For example, Johnson & Sheppard[16] (2004) and Brainard and Carlin [15] illustrated that high school performance (math and science) predicted students' decisions to enroll in 4-year engineering institutions, and French et al.[20] illustrated that it (high school performance) predicted college GPA. Cohen and Deterding[19] studied undergraduate engineering programs at the US institutions from academic years 1999–2000 through 2004–2005 to conclude that the issue for engineering education is more of recruitment than retention. Further, Godwin et al.[32] advised that efforts to recruit women should not solely focus on building physics, math, or engineering identities but should also emphasize their empowerment in changing their world through engineering.

Insight 2: Women students rely on their family members for choosing their careers

Many authors have highlighted the influence of high school teachers on students' career choices and preparation for the choices[29,30,26,33], it appears that women students also rely on their parents and other family members for making the choices[34].

Insight 3: The K12 system must help women students to develop social capital and navigational capital

The K-12 system must facilitate developing social capital (resources embedded in a social structure that are accessed or mobilized in purposive actions)[29,30] and navigational capital (understanding how to successfully navigate educational institutions with dominant cultural norms)[26] to ease engineering education of women. The system also must prevent discouragement of women by peers, teachers and parents from joining STEM courses[35].

Insight 4: Admission systems seem to favor men students.

The admission system favors men students by using factors such as performance in math and science, which better predict their success, and ignore factors such as motivation, propensity toward deep learning, and self-perception of leadership ability, which better predict success of women students[36].

Transition to college

Insight 1: Bridge programs apparently haven't been utilized to tackle gender underrepresentation.

We came across many studies, such as Morning et al[37] and Lam[38] that used bridge programs to overcome transition difficulties of ethnic minority students, but did not come across any similar study for women students.

Insight 2: Ethnic minority women tend to have transition difficulties due to difficulties in using resources

Martin et al.[29] discussed transition difficulties of Hispanic women students due to delayed recognition or identification of available resources resulting in slow access and activation of resources.

Insight 3: Curricular changes can be made to ease transition of women students into engineering programs.

Hoit and Ohland showed, with statistically significant evidence, that presenting the real engineering content, in the first-year itself, helps retain women students[31]. They changed the introduction to engineering course to a laboratory format, where they employed active learning with smaller class sizes, and rotated students through laboratories in each undergraduate engineering department. They studied three different cohorts, wherein students could choose either the new laboratory format, which 42 women students did; or traditional lecture based format, which 92 women students did. The authors found women retention (remaining in the program till the third year of study) in the lecture-based format was at 16%, and that in the laboratory format was at 52%. Brainard and Carlin suggest including core courses in sophomore instead of junior year[15] to ease students' transition into engineering.

College Experience

Retention and Persistence

We have fifteen papers in our sample that analyze chances of retention, intention of retention, and actual retention of women students. Appendix B lists the fifteen papers that compare retention, graduation rates, and academic performance of women engineering students with men engineering students.

Insight 1: Women retention does not appear to be lower, and appears to be on the rise.

Five of the fifteen retention articles do not find any difference in retention between gender[39-40] and one article[15] analyzes retention of only women students. The latter tracks individual students and indicates women retention for freshmen students to be in the range of 80-97%, and for sophomore students to be in the range of 82 to 89%; these retention numbers are on the higher side as compared to the normally reported numbers.

One study[22] comments on the intention of retention of students in the first year, which was found to be lower in the case of women students. Some researchers have documented[41] women underestimating their performance, which may increase their intention to quit. Many researchers[42,15,43, 44] point out lower self-efficacy of women students and its impact on the retention[45,35].

Four studies indicate higher retention of men students [16,20,25,35]. The French et al. study works on the odds ratio. None of the four studies has showed statistically significant difference in men's retention, though. Three studies indicate higher retention for women[19,18,46]. Cohen's study has showed statistically higher retention for women students. The studies that are in favor of men retention have considered the MIDFIELD database and NC university database; while the ones that are in favor of women retention have considered a national database (Engineering workforce commission- EWC) of 1999-2001 graduating students and a mid-Atlantic college database. Three of the four studies that indicate higher retention for men compute 4-year retention, while the NC study[35], which indicates poor retention of women, computes three-year retention. Min et al.[25], who compute four year retention resulting in favorable men retention, believe that men may be leaving engineering after 4 years.

Thus, not every study shows women experiencing attrition at higher rates than men, which appears to be a preconceived notion. The studies that show higher men retention appear to be older than the ones that show higher women retention. We tend to think that women retention does not appear to be lower but recently it appears to be rising.

Insight 2: Women retention appears not due to the lack of abilities, but due to social barriers, and can be countered with better social integration in their colleges.

Women choosing engineering majors face various barriers to persistence such as the lack of self-confidence and fear of not getting accepted in their departments, which do not relate to their abilities[15], and perhaps cause women students to drop out earlier in the program[25]. Felder et al.[35] found that women were more likely to have transferred out in good standing and much more likely to have transferred out after failing a course Generally, lower levels of self-efficacy influences attrition rates[15,47] and women students have poor self-efficacy than men students[41].

Self-efficacy may be interplaying with academic motivation in determining persistence[20]. Litzler and Young[22] provide three constructs for academic motivation – 'At-Risk of Attrition', 'Committed with Ambivalence' and 'Committed'. While they found women to be more likely than men to be in the 'At-Risk of Attrition' (odds 0.43 to 0.71) group; better experiences can take women students to 'Committed with Ambivalence' compared to the 'Committed' group (odds ratio 0.73) group. Johnson et al.[16] have found increased attrition rates of women engineers due to disillusionment with engineering and the lack of interest in potential lifestyles associated with engineering jobs. Hutchison et al. tried to understand the sources of self-efficacy and found both men and women citing motivation towards success, understanding / learning of course material, and computing abilities as the factors that influenced their efficacy beliefs the most[48]. 'Understanding/learning course material' (72% for women vs 55% for men), 'not having computing ability' (32% for women vs 12%), 'not getting help' (38% for women vs 19% for men) affected women more significantly[48]. Woodcock et al.[49] brings in another element - providing opportunities for working in a communal or collaborative manner – to take care of social barriers, which can help in improving women's representation. They also claimed that that women's 'thing orientation' is poorer than men but has a significant impact on their intentions to persist in engineering.

Retention measures such as eighth semester persistence instead of six-year graduation help white men as discovered by Ohland et al[50].

Graduation Rates

Insight 1: There is virtually no difference in the graduation rates of women and men students.

We have three articles that discuss graduation rates. Brainard and Carlin tracked only women students (N=672) to find their graduation rates to be 71%[15]. Ohland et al. in their study of nine southeast public universities found virtually no difference between men (61%) and women students (60%) in six-year graduation rates[50]. Zhang et al.[51] studied graduation rate at 9 universities for over 15 years and found that 3 universities showed better (six year) graduation rate for men, one showed better for women, and pooled data did not show any difference. Thus, it seems that there is virtually no difference in the graduation rates of women and men students.

Academic Performance (GPA)

Insight 1: Women's overall academic performance seems to be better, but does not translate into proportionally higher retention.

We have six articles that commented on academic performances. Three studies[20,52,53] indicated better performance of women students, two indicated mixed performance [35,54], one indicated no difference in the genders[55], and one indicated better performance of men students[41].

The French et al. study[20] found women students having statistically significant better GPA, when they constructed hierarchical linear regression with GPA as the dependent variable and gender as an independent variable. Bernold et al.[53] found women students' first semester CGPA at 3.24, while men students were languishing at 2.97. The difference widened at the end of the first year to 3.27 and 2.89 and was statistically significant. They further covaried GPA (of freshman, sophomore, and junior years) with SATM (SAT-mathematics) and found women students having better GPA than men students in all four learning type measures. The Hawks and Spade study[52] indicated that the first semester CGPA of women students was a shade better than men students (2.79 vs 2.70).

Felder et al.[35] found that, at the end of four years, women students' overall CGPA was higher (3.08 vs 3.02) but chemical engineering courses' GPA was lower (2.55 vs 2.64). Mesa et al., based on their study of a set of first year engineering students from University of Michigan from 1997 through 2003 indicated that women had a statistically significant reduction of 0.059 in the Physics 240 grade but a significant increase of 0.074 in the Math GPA[54]. Felder et al.[55] found almost identical passing rates for males and females for CHE 205 (introductory sophomore course on Chemical Process Principles) at NC state university. Jones et al.[41] studied first year GPA of nine engineering related courses and found men students having better (but not statistically significant) GPA (3.12 vs 2.97). They also found that, near the end of the first year, self-efficacy was the best predictor of GPA for men (explained 33% of the variance) and women (explained 41% of the variance).

Insight 2: Women students tend to have better professional skills such as communication, time management, and team skills.

Lumsdaine and Lumsdaine[56] studied the thinking preferences using the Herrmann Brain Dominance Instrument (HBDI), which reveals the preferences in four different ways : A = analytical-logical-quantitative, B =sequential-organized-detailed, C = interpersonal-sensory-kinesthetic, and D = innovative-holistic-conceptual thinking. They did not find any differences in men and women engineering students' scores in quadrants A, B, and D; but found women scoring significantly higher in quadrant C. The quadrant C thinking preference (teamwork skills) of women students creates uncomfortable classroom climates for them. Further, women students were found more adept at the professional skills such as communication and team skills[34], harboring positive attitudes toward roles and responsibilities, and having better awareness of engineering ethics [57]. However, Hunkeler and Sharp[58] did not find a significant effect of gender distribution on group performance in their four-year study of a senior laboratory course.

Lackey et al.[21] found that journal score of a course predicted the first year GPA. The correlation was stronger for men than women students, whose better predictor was high school GPA. The journal score represents student engagement, attitude, initiative, time management skills, study habits, and willingness to persevere. Since women students, in general, do better on those attributes, the authors believed that the journal score did not influence their GPA as much as men students.

Insight 3: There may not be any gender difference in creativity skills.

Charyton and Merrill[59] measured creative engineering design and general creativity of engineering students and found no difference in general creativity across genders but did find women students better in creative engineering design in the retest. They could not explain the results, though.

Women's better academic performance and motivation to study engineering does not appear to result in proportionate better retention. Felder et al.[35] study points out that the women in his study entered chemical engineering with credentials (academic, social, attitude towards learning, and motivation to study) equal to or better than those of their men counterparts, but exhibited erosion, relative to the men, in both academic performance and confidence as they progressed through the curriculum. Hecht et al.[34] echoed similar pattern – women are more likely than men to change to another major when they become dissatisfied with their class standing. This may be due to their feeling of being isolated in the academic environment. In general, they require proving their worth more than their men colleagues. Felder et al.[35] categorically state that women are as capable as men to become successful engineering students and outstanding engineers. However, their poor academic performance and lower confidence levels are due to a variety of social factors rather than intrinsic sexual differences, and those factors can be neutralized. Hawks and Spade[52] found that women's attitudes toward their abilities, and not their actual academic achievement differ from men.

Perhaps, it may be incorrect to use GPA as a monolithic variable to indicate academic performance and may require segregation of the GPA in various groups of courses or inclusion of other measures such as development of graduate attributes. That may provide more pertinent insights.

Academic and social integration

Integrating women students academically and socially depends on faculty's general demeanor towards them and use of research-based instructional strategies, and overall instructional environment and contextual support. Reichert and Absher[60] have pointed out that more than the contents of the program, the care with which they are executed decides their benefits. Felder et al.'s study[35] had relatively more women coming from urban areas and had more educated parents, which should have helped in, if not in academic, at least in social integration. However, they did not find it happening. The women in the study had greater anxiety and lower confidence levels than the men.

Faculty

Insight 1: Faculty, the key element of an education system, can help under-represented students succeed.

Quality of experience of students with faculty members is positively correlated with persistence and sense of belonging in the college of engineering; and is negatively correlated with attrition as discovered by many authors[30,61,15]. Faculty has to be accessible and create classroom / discipline-specific environments that welcome, include, and support participation of all students, especially underrepresented students[16]. It is also important that faculty has to stave off the stereotype threats[62] and avoid disparaging statements about women students, which could lower their self-confidence[35]. While Felder et al.[35] point out the need to educate professors and academic advisors about the problems and needs of women students, Murphy et al.[33] advocate faculty exhibiting behaviors that women students perceive as a high level of care for them as individuals. Foor et al.[63] advocate that engineering educators be trained in critical cultural theory and be aware that cultures are engineered by people. The educators, they point out, have to change the dominant culture to be more inclusive of diversity, especially of individual diversity (i.e. breadth of experience of an individual) of both faculty and students. Foor et al.[63] also recommend faculty to pay attention to "us" and "them" classroom dynamics that are established as a result of "capital differences" among diverse students and to be aware that students with average grades can also excel as engineers. In general, Foor et al.[63] insist that faculty must make under-represented students feel "more welcome" in engineering colleges. Thus faculty can certainly help students develop the critically required social capital[29] and cultural wealth[26].

Insight 2: Research-based instructional strategies influence academic integration of all the students, more so of women.

Faculty members use of research-based instructional strategies influence learning of all the students, more so of underrepresented students like women[31,64]. That may be due to the strategies creating easier opportunities for students to interact with their faculty members and peers. While men rate library, women rate other students as an important source of information[34], which indicate the importance of cooperative learning for women students.

Contextual support

Insight 3: Contextual support influences social integration of all the students, more so of women

While contextual support is largely governed by faculty members; it also includes other staff and students. Raelin et al.[47], include a number of mechanisms such as providing financial aid, mentoring, facilitating more students to live on campus, and establishing and developing professional clubs, and living-learning communities in contextual support. They found women retention to increase from 21% to 47% as the contextual support changes from low to high level, and the men retention, with the same change, to increase mildly from 30% to 33%. Ro and Knight[64] and Murphy et al.[33] also observed women students' success can be disproportionately improved by the factors such as mentorship, professional clubs, living-learning communities, and peer support. Litzler and Young[22] have found that better support can help overcome the risk of attrition of women students. While developing minority programs, it is important to understand that the gender minority is perceived to be a difficult barrier than ethnic minority[30] and the system should not treat minority students and 'at risk' students synonymously[60].

Felder et al.[35] and Johnson and Sheppard[16] support Raelin et al. in providing women engineering students with women role models and mentors, and point out the critical need of addressing the shortage of women faculty members. Until the shortage is addressed, Felder et al.[35] suggest that colleges can rely on peer mentoring i.e. mentoring by women graduate students and upper-class undergraduates to freshman and sophomore students.

Martin et al.[29] support the need for involving family in educational process and developing familial capital as articulated by Samuelson and Litzler[26]. Martin et al.[29] highlight the need of improving parental education regarding financial aid, expected engineering course load, and long-term benefits of earning an engineering degree, and emphasize designing events and activities for parents by taking care of their language preferences. Samuelson and Litzler[26] suggest family engagement programs to encourage familial capital by bringing families to campus and providing them with information on how best to support students.

Minority programs and societies are special instances of institutional support and help underrepresented students in academic and social integration, primarily by bringing them in contact with peers, seniors, and alumni students[16,14,30,29,15,64,35]. There have been specific studies of Society of Women Engineers (SWE) helping women students succeed[16,15]. Many authors found that having formal structures such as SWE (Society for Women Engineers) and professional clubs can go a long way in providing contextual support to women students, [16,29,35,64], thereby helping them develop social capital[29]. Felder et al.[35] believe that such organizations can provide career guidance and emotional support to women students and a natural forum for successful women engineers to return to campus to portray a realistic and positive picture of engineering as a career for women. Ro and Knight[64] claim that women students, who participated in non-engineering clubs or activities reported greater improvement in fundamental skills, contextual competence, and communication skills than men. Those women students, who participated in engineering clubs for women or underrepresented minorities also reported greater improvement in communication skills than men, although the improvement was lesser than for those who participated in non-engineering clubs or activities. Johnson and Sheppard [16] found a mixed impact of such organizations on retention rates of underrepresented students, but found evidence that the most successful programs provide strong financial support, create a successful learning environment by ensuring access to role models, faculty mentorship, and organizing peer support. Martin et al.[29] recommend supporting organizations of underrepresented students, which can help them in evolving peer networks, which can result in development of social capital of those students. All this amounts to creating successful and supportive learning environment as articulated by many authors[16,29,33,47].

Insight 4: Providing diverse ethnic environment helps women of all ethnicities

Trenor et al. [30] have found that diverse ethnic environments (where no group is singled out as minority) helps in achieving a highly supportive educational environment for students of all ethnicities, which matters more for women students.

Insight 5: Departments level initiatives also can provide contextual support

The contextual support can also be provided by individual departments, by presenting diversity, collegiality, and multifaceted professional image that is relevant to women students' lives. The departments having diverse faculty and staff, who respect their colleagues' abilities and work together towards a common departmental goal catalyzes better contextual support. Also, the departments that offer diverse experiences and pave the way for jobs that are "pro-social" or humanistic, provide comprehensive type of life, and value competence in several areas simultaneously are liked by women students[33,61].

Professional integration

This is an important area but has not yet attracted sufficient attention of researchers.

Insight 6: Women tend to have better professional skills but have subdued career aspirations.

Women students were found more adept at the professional skills such as communication and team skills[34,56], harboring positive attitudes toward roles and responsibilities, and having better awareness of engineering ethics[57]. Professional setttings tend to have teams with various gender compositions (majority men, majority women, mixed) and Laeser[65] found that the composition influences team functioning and quality of team products.

Researchers also found that women students tend to be more practical and are influenced by teachers, parents, and other family members regarding their career choices[34].While they give importance, like their men counterparts, for the rewarding careeers [34] and their extrinsic utility value[41]; they tend to give more importance to availability of information regarding career opportunities and financial returns[34], and job availability and job security[52]. While Hawks and Spade[52] found that women do not give importance to engineering fitting their interest; Jones[41] found that both men and women give equal value to it.

Hawks and Spade[52] found women having subdued career aspirations i.e. they do not see themselves in supervisory positions and earning money at par with their men counterparts. The authors deduce that the conflicts between professional and personal responsibilities, and not abilities and attitude, as the reason for the subdued aspirations. They also found that some women students do feel the lack of confidence in their ability to succeed as a barrier and expect to be employed in fields other than engineering. They, further, found that women tend to have non-traditional views about their careers vis-a-vis men. For example, women, more likely than men, agree that a wife should make long-range career plans just as her husband does, disagree that a wife should leave her job to follow a husband's career, and also disagree that men are financially responsible for supporting the family. At the same time, they hold traditional views about their roles in family responsibility, especially child-rearing. Such a mix of traditional and non-traditional views, may result in role-conflicts, and perhaps in the subdued career aspirations. Essentially, there is a huge difference in the way women and men think about their careers and family responsibilies. It seems that men are blissfully ignorant of women's career aspirations and expectations about the men's contribution in family responsibilities[52]. The educators and parents need to work on these aspects so that women can realize their potential in contributing to the engineering profession.

Conclusion

The US has 56% women among college graduates[66], but less than 20% among engineering graduates[67]. In the professional world, the situation is gloomier. National Science Foundation reports that12.9% of all US engineers are women and the percentage thins rapidly as the seniority level rises[68]. That motivated us to carry out a systematic review of literature on analyzing success of women engineering students. We focused on the most prominent engineering education journal, JEE and studied the relevant 39 articles that were published between from 1993 through 2016.

The articles appear to be using more advanced statistical techniques and qualitative or mixed methods, and appear to be coming from a few institutions such as Purdue and more from recently established education departments. The articles reveal that the commonly held notion of the women having higher attrition and lower graduation rates may not be true. In fact, the women students appear to be doing well on those measures, despite facing stereotype threats in both academic and social environment. We found the solution space for improving success of women students in engineering in the US focusing on recruitment in K-12, community colleges, and regular colleges; and better academic and social integration with the help of refined instructional environment and superior contextual support to women students.

In the literature review we came across only two papers providing solutions with evidence. As noted by other researchers, even though the justification for many solutions appears to be intuitively sound, the lack of empirical support makes generalizability to other programs difficult[69]. Further, most of the insights appear to be originating from a few institutions and may depend on institutional settings. Thus, practitioners need to understand both the sources setting and their setting before attempting to utilize these insights. Future research to identify how insights depend on institutional settings could better support educators in utilizing appropriate insights in their contexts. Moreover, we came across only one paper in JEE that study countries outside the US. The treatment of such under-representations in other countries may offer some useful directions and solutions to the US engineering education system and vice versa.

All the studies we reviewed define success in the academic and not the professional context. Given the critical need for diversity in the workforce, professional success requires significant attention. In fact, engineering students' real success is in their professions. From that perspective, longitudinal studies that track professional performance of alumni and linking that to different dimensions of college performance may help. Currently, academic performance is largely researched in terms of GPA and changing that to disaggregated GPAs and graduate attributes can help.

While the problem of lower numbers graduating women engineers is clear to all, there are different views about right approaches. Ohland et al.[50] point out that treating all students the same is not actually equitable as a given treatment may have different effects on different groups. On the other hand, some argue that any student with the will to excel, regardless of race or gender, would benefit, if apprised of effective learning techniques and, if exposed to good teaching practices[60]. We believe that the truth may lie somewhere in between. While some techniques and practices may not influence populations differently, some clearly do; and implementation will play a significant role in the results. Thus, we agree with Reichert and Absher[60] when they say that programs must be implemented with care and concern for the local context.

Our study has some limitations. The term 'student success' appears to be in the process of getting formalized and the searches on the term may have missed some papers. While we have used many associated search terms such as performance, persistence, etc. and gotten our search strategy reviewed by experts, it is possible that, we still may have missed some relevant papers. Our review presents qualitative and not statistical meta-analysis as there are very few papers that present quantitatively proven solutions. Our limitations also include not covering LGBTQA

(Lesbian, Gay, Bisexual, Transgendered, Questioning, and Allied) students and including explicit search terms on recruitment.

Like Pawley et al.[11] our systematic review was limited to JEE – the premier US journal of engineering education. To more deeply understand the issues, a meta-review that includes journals such as IJEE (International Journal of Engineering Education), AEE (Advances in Engineering Education), and JWMSE (Journal of Women, Minorities, in Science and Engineering) broadly from the US perspectives; and EJEE (European Journal of Engineering Education) and AAEE (Australasian Association for Engineering Education) from the global perspectives is warranted. We, however, believe that analysis reported in the paper can help in understanding and catalyzing the success of women engineering students and can provide foundational support towards more comprehensive research.

Acknowledgements

We thank the division program chair and anonymous reviewers for their thoughtful review comments, which helped us enhance the quality of the paper. We also thank our collegues at CRICPE and Prof Felder for early reviews of the paper.

References

1. Rosin, H., *The end of men: And the rise of women*. 2012: Penguin.
2. Beede, D.N., et al., *Women in STEM: A gender gap to innovation.* 2011.
3. Chen, X., *STEM Attrition: College Students' Paths into and out of STEM Fields. Statistical Analysis Report. NCES 2014-001.* National Center for Education Statistics, 2013.
4. Mayer, P., *Guidelines for writing a review article.* Zurich-Basel: Plant Science Center. Dostupné z http://www. plantscience. ethz. ch/education/Masters/courses/Scientific_Writing, 2009.
5. Gough, D., S. Oliver, and J. Thomas, *An introduction to systematic reviews*. 2012: Sage.
6. Cook, D.A. and C.P. West, *Conducting systematic reviews in medical education: a stepwise approach.* Medical education, 2012. **46**(10): p. 943-952.
7. Finfgeld, D.L., *Metasynthesis: The state of the art—so far.* Qualitative health research, 2003. **13**(7): p. 893-904.
8. Borrego, M., M.J. Foster, and J.E. Froyd, *Systematic literature reviews in engineering education and other developing interdisciplinary fields.* Journal of Engineering Education, 2014. **103**(1): p. 45-76.
9. Noguchi, J., *The science review article: An opportune genre in the construction of science*. Vol. 17. 2006: Peter Lang.
10. Van Epps, A.S., *Beyond JEE: Finding publication venues to get your message to the 'right'audience.* 2013.
11. Pawley, A.L., C. Schimpf, and L. Nelson, *Gender in Engineering Education Research: A Content Analysis of Research in JEE, 1998–2012.* Journal of Engineering Education, 2016. **105**(3): p. 508-528.
12. Borrego, M., M. Foster, and J.E. Froyd, *What Is the State of theArt of Systematic Reviewin Engineering Education?* Journal of Engineering Education, 2015. **104**(2): p. 212-242.
13. Salleh, N., E. Mendes, and J. Grundy, *Empirical studies of pair programming for CS/SE teaching in higher education: A systematic literature review.* IEEE Transactions on Software Engineering, 2011. **37**(4): p. 509-525.
14. Lee, W.C. and H.M. Matusovich, *A Model of Co-Curricular Support for Undergraduate Engineering Students.* Journal of Engineering Education, 2016. **105**(3): p. 406-430.
15. Brainard, S.G. and L. Carlin, *A six-year longitudinal study of undergraduate women in engineering and science.* Journal of Engineering Education, 1998. **87**(4): p. 369-375.
16. Johnson, M.J. and S.D. Sheppard, *Relationships between engineering student and faculty demographics and stakeholders working to affect change.* Journal of Engineering Education, 2004. **93**(2): p. 139.
17. May, G.S. and D.E. Chubin, *A Retrospective on Undergraduate Engineering Success for Underrepresented Minority Students.* Journal of Engineering Education, 2003. **92**(1): p. 27-39.

18. Atwood, S.A. and J.E. Pretz, *Creativity as a Factor in Persistence and Academic Achievement of Engineering Undergraduates.* Journal of Engineering Education, 2016.
19. Cohen, C.C.d. and N. Deterding, *Widening the net: National estimates of gender disparities in engineering.* Journal of Engineering Education, 2009. **98**(3): p. 211-226.
20. French, B.F., J.C. Immekus, and W.C. Oakes, *An examination of indicators of engineering students' success and persistence.* Journal of Engineering Education, 2005. **94**(4): p. 419-425.
21. Lackey, L.W., et al., *Efficacy of Using a Single, Non-Technical Variable to Predict the Academic Success of Freshmen Engineering Students.* Journal of Engineering Education, 2003. **92**(1): p. 41-48.
22. Litzler, E. and J. Young, *Understanding the risk of attrition in undergraduate engineering: Results from the project to assess climate in engineering.* Journal of Engineering Education, 2012. **101**(2): p. 319.
23. Holloway, B.M., et al., *Research‐Informed Policy Change: A Retrospective on Engineering Admissions.* Journal of Engineering Education, 2014. **103**(2): p. 274-301.
24. Adams, L., *Ten Commandments of Egoless Programming.* Tech Republic, 2002.
25. Min, Y., et al., *Nonparametric survival analysis of the loss rate of undergraduate engineering students.* Journal of Engineering Education, 2011. **100**(2): p. 349-373.
26. Samuelson, C.C. and E. Litzler, *Community Cultural Wealth: An Assets‐Based Approach to Persistence of Engineering Students of Color.* Journal of Engineering Education, 2016. **105**(1): p. 93-117.
27. Villa, E.Q., et al., *Affinity research groups in practice: Apprenticing students in research.* Journal of Engineering Education, 2013. **102**(3): p. 444-466.
28. Lichtenstein, G., et al., *An engineering major does not (necessarily) an engineer make: Career decision making among undergraduate engineering majors.* Journal of Engineering Education, 2009. **98**(3): p. 227-234.
29. Martin, J.P., D.R. Simmons, and S.L. Yu, *The role of social capital in the experiences of Hispanic women engineering majors.* Journal of Engineering Education, 2013. **102**(2): p. 227-243.
30. Trenor, J.M., et al., *The relations of ethnicity to female engineering students' educational experiences and college and career plans in an ethnically diverse learning environment.* Journal of engineering education, 2008. **97**(4): p. 449-465.
31. Hoit, M. and M. Ohland, *The Impact of a Discipline‐Based Introduction to Engineering Course on Improving Retention.* Journal of engineering education, 1998. **87**(1): p. 79-85.
32. Godwin, A., et al., *Identity, Critical Agency, and Engineering: An Affective Model for Predicting Engineering as a Career Choice.* Journal of Engineering Education, 2016. **105**(2): p. 312-340.
33. Murphy, T.J., et al., *Achieving parity of the sexes at the undergraduate level: A study of success.* Journal of Engineering Education, 2007. **96**(3): p. 241-252.
34. Hecht, L.F., et al., *Becoming an Aerospace Engineer: A Cross‐Gender Comparison.* Journal of Engineering Education, 1995. **84**(3): p. 263-270.
35. Felder, R.M., et al., *A longitudinal study of engineering student performance and retention. III. Gender differences in student performance and attitudes.* Journal of Engineering Education, 1995. **84**(2): p. 151-163.
36. Holloway, B.M., et al., *Research-Informed Policy Change: A Retrospective on Engineering Admissions.* Journal of Engineering Education, 2014. **103**(2): p. 274-301.
37. Morning, C. and J. Fleming, *Project Preserve: A program to retain minorities in engineering.* Journal of Engineering Education, 1994. **83**(3): p. 237-242.
38. Lam, P.C., D. Doverspike, and R.P. Mawasha, *Predicting success in a minority engineering program.* Journal of Engineering Education, 1999. **88**(3): p. 265-267.
39. Moller-Wong, C. and A. Eide, *An engineering student retention study.* Journal of Engineering Education, 1997. **86**(1): p. 7-15.
40. Ohland, M.W., et al., *Persistence, engagement, and migration in engineering programs.* Journal of Engineering Education, 2008. **97**(3): p. 259-278.
41. Jones, B.D., et al., *An Analysis of Motivation Constructs with First-Year Engineering Students: Relationships Among Expectancies, Values, Achievement, and Career Plans.* Journal of Engineering Education, 2010. **99**(4): p. 319-336.
42. Huang, P.M. and S.G. Brainard, *Identifying determinants of academic selfconfidence among science, math, engineering, and technology students.* Journal of women and minorities in science and engineering, 2001. **7**(4).
43. Tokar, D.M., et al., *Precursors of learning experiences in social cognitive career theory.* Journal of Vocational Behavior, 2007. **71**(3): p. 319-339.

44. Bjorklund, S.A., J.M. Parente, and D. Sathianathan, *Effects of faculty interaction and feedback on gains in student skills.* Journal of Engineering Education, 2004. **93**(2): p. 153-160.
45. Marra, R. and B. Bogue. *Women engineering students self efficacy: a longitudinal multi-institution study*. in *Proceedings of the 2006 WEPAN Conference*. 2006. Citeseer.
46. Brown, A.R., C. Morning, and C. Watkins, *Influence of African American engineering student perceptions of campus climate on graduation rates.* Journal of Engineering Education, 2005. **94**(2): p. 263-271.
47. Raelin, J.A., et al., *The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention.* Journal of Engineering Education, 2014. **103**(4): p. 599-624.
48. Hutchison, M.A., et al., *Factors Influencing the Self-Efficacy Beliefs of First-Year Engineering Students.* Journal of Engineering Education, 2006. **95**(1): p. 39-47.
49. Woodcock, A., et al., *Engineering students' beliefs about research: Sex differences, personality, and career plans.* journal of Engineering Education, 2012. **101**(3): p. 495-511.
50. Ohland, M.W., et al., *Race, Gender, and Measures of Success in Engineering Education.* Journal of Engineering Education, 2011. **100**(2): p. 225-252.
51. Zhang, G., et al., *Identifying Factors Influencing Engineering Student Graduation: A Longitudinal and Cross-Institutional Study.* Journal of Engineering Education, 2004. **93**(4): p. 313-320.
52. Hawks, B.K. and J.Z. Spade, *Women and men engineering students: Anticipation of family and work roles.* Journal of Engineering Education, 1998. **87**(3): p. 249-256.
53. Bernold, L.E., J.E. Spurlin, and C.M. Anson, *Understanding Our Students: A Longitudinal-Study of Success and Failure in Engineering With Implications for Increased Retention.* Journal of Engineering Education, 2007. **96**(3): p. 263-274.
54. Mesa, V., O. Jaquette, and C.J. Finelli, *Measuring the impact of an individual course on students' success.* Journal of Engineering Education, 2009. **98**(4): p. 349-359.
55. Felder, R.M., et al., *A longitudinal study of engineering student performance and retention: I. Success and failure in the introductory course.* Journal of Engineering Education, 1993. **82**(1): p. 15-21.
56. Lumsdaine, M. and E. Lumsdaine, *Thinking preferences of engineering students: Implications for curriculum restructuring.* Journal of Engineering Education, 1995. **84**(2): p. 193-204.
57. Lathem, S.A., M.D. Neumann, and N. Hayden, *The Socially Responsible Engineer: Assessing Student Attitudes of Roles and Responsibilities.* Journal of Engineering Education, 2011. **100**(3): p. 444-474.
58. Hunkeler, D. and J.E. Sharp, *Assigning functional groups: The influence of group size, academic record, practical experience, and learning style.* Journal of Engineering Education, 1997. **86**(4): p. 321-332.
59. Charyton, C. and J.A. Merrill, *Assessing general creativity and creative engineering design in first year engineering students.* Journal of engineering education, 2009. **98**(2): p. 145-156.
60. Reichert, M. and M. Absher, *Taking another look at educating African American engineers: The importance of undergraduate retention.* Journal of Engineering Education, 1997. **86**(3): p. 241-253.
61. Walden, S.E. and C. Foor, *"What's to keep you from dropping out?" Student Immigration into and within Engineering.* Journal of Engineering Education, 2008. **97**(2): p. 191-205.
62. Bell, A.E., et al., *Stereotype threat and women's performance in engineering.* Journal of Engineering Education, 2003. **92**(4): p. 307-312.
63. Foor, C.E., S.E. Walden, and D.A. Trytten, *"I wish that I belonged more in this whole engineering group:" Achieving individual diversity.* Journal of Engineering Education, 2007. **96**(2): p. 103-115.
64. Ro, H.K. and D.B. Knight, *Gender Differences in Learning Outcomes from the College Experiences of Engineering Students.* Journal of Engineering Education, 2016. **105**(3): p. 478-507.
65. Laeser, M., et al., *Engineering design: Examining the impact of gender and the team's gender composition.* Journal of Engineering Education, 2003. **92**(1): p. 49-56.
66. NCES. *Digest of education statistics*. 2015 04/25/2017]; Available from: https://nces.ed.gov/programs/digest/d15/tables/dt15_105.20.asp?current=yes.
67. Yoder, B., *Engineering by the numbers. American Society for Engineering Education*. 2016.
68. Randsad. *Diversity in engineering in 2017*. 2017 [cited 2018]; Available from: https://www.randstad.com/workforce-insights/workforce360/archives/diversity-in-engineering-in-2017_157/.
69. Hermond, D., *Measuring the retention strategies of a minority engineering program: A service quality perspective.* Journal of Engineering Education, 1995. **84**(4): p. 395-400.

Appendix A – Details of the papers selected (40)

Author Names	Authors' Details					Method	Title	Year	Category	Research Question	Type
	No of authors from Core Engineering	**Core engineering Departments**	**No from Other departments**	**Other department details**	**University**						
Felder, et al.	2	Chemical, Engg	3	2 Psychology 1 Statistics	NC State	Quant	A longitudinal study of engineering student performance and retention. I. Success and failure in the introductory course	1993	Periphery	What are the predictors of success or failure in an introductory course, and by extension, in the chemical engineering curriculum.	Analysis
Hecht et al.	NA	NA	NA	NA	Indiana	Quant	Becoming an aerospace engineer: a cross-gender comparison	1995	Core	What is the extent to which genders differ in factors that lead to the choice to study aerospace engineering, their current level of satisfaction with that choice, and their career-related goals and aspirations	Analysis + solution

Felder, et al.	3	Chemical Engineering		2 Statistics	NC State	Quant	A longitudinal study of engineering student performance and retention. iii. gender differences in student performance and attitudes	1995	Core	Examines gender differences in the students' academic performance, persistence in chemical engineering, and attitudes toward their education and themselves.	Analysis + solution
Lumsdaine and Lumsdaine	NA	NA	NA	NA	Michigan Technological	Quant	Thinking preferences of engineering students: Implications for curriculum restructuring	1995	Periphery	Finding insights as well as quantitative answers to questions pertaining to thinking skills based on the HBDI profiles	Analysis
Moller-Wong, and Eide	2	Industrial, Mechanical	-	-	Iowa state	Quant	An engineering student retention study	1997	Periphery	Identify students who are potentially at risk of attritions	Analysis
Hunkeler and Sharp	NA	NA	NA	NA	Vanderbilt	Quant	Assigning functional groups: The influence of group size, academic record, practical	1997	Periphery	Which factors affect performance of student groups?	Analysis

							experience, and learning style				
Hoit and Ohland	2	Civil, Chemical	-	-	University of Florida	Quant	The impact of a discipline-based introduction to engineering course on improving retention	1998	Core	What is the impact of a discipline-based introduction to engineering course on improving retention of different groups?	Analysis + solution with evidence
Brainard and Carlin	-	-	2	WIE, Psychology	University of Washington	Mixed	A six-year longitudinal study of undergraduate women in engineering and science	1998	Core	Examine factors affecting retention of women in science and engineering; and to evaluate the effectiveness of WIE programs.	Analysis + solution
Hawks and Spade	NA	NA	NA	NA	Bentley and Lehigh	Quant	Women and men engineering students: anticipation of family and work roles	1998	Core	What are the anticipated role conflicts of women and men engineering students	Analysis + solution
Bell et al.	1	Electrical	3	Psychology	Virginia Tech, Waterloo	Quant	Stereotype threat and women's performance in engineering	2003	Core	What is the effect of stereotype threats on women's performance	Analysis + solution

Bjorklund et al.	1	Engineering design	2	Education, Student affairs	Pennsylvania	Quant	Effects of faculty interaction and feedback on gains in student skills	2003	Periphery	What is the relationships between engineering faculty teaching practices, classroom climate, and students' perceptions of their gains in communication skills, problem solving skills, occupational awareness, and engineering competence in a curriculum emphasizing engineering design activities	Analysis
Lackey et al.	2	Biomedical, Mech	2	Tech communication	Georgia Tech, Mercer	Mixed	Efficacy of using a single, non-technical variable to predict the academic success of freshmen engineering students	2003	Periphery	Finding the effectiveness of using a course journal score of the freshman year to predict GPA of freshmen engineering students	Analysis

Laeser et al.	1	Design engineering	3	Comp Science and WIE	Colarado School of mines	Quant	Engineering design: examining the impact of gender and the team's gender composition	2003	Core	How do the team functions of men and woman engineering design students differ during the team process?	
Johnson and Sheppard	2	Mechanical	-	-	Stanford	Quant	Relationships between engineering student and faculty demographics and stakeholders working to affect change	2004	Core	What is the progress of the high school class through the engineering pipeline and beyond, specifically focusing on women and underrepresented minority students?	Analysis + solution
Zhang et al.	2	Chemical, General	2	Education, Oncology	Florida, Clemson and Stanford	Quant	Identifying factors influencing engineering student graduation: a longitudinal and cross-institutional study	2004	Periphery	What is the influence of preexisting demographic and academic factors on graduation?	Analysis

French et al.	-		-	3	Education Studies	Purdue	Quant	An examination of indicators of engineering students' success and persistence	2005	Core	Student success and persistence within the major and university were examined along with gender differences	Analysis
Hutchison et al.	3		Chemistry	1	Education	Purdue	Quali	Factors influencing the self-efficacy beliefs of first-year engineering students	2006	Core	Which aspects of students' first engineering course influence their self-efficacy beliefs, and how do these aspects vary by gender?	Analysis
Bernold et al.		1	Civil	2	English, Assessment (admin)	NC State	Quant	Understanding our students: A longitudinal-study of success and failure in engineering with implications for increased retention	2007	Core	Enhance educators' understanding of the factors that influence student retention in engineering – also study gender differences	Analysis
Murphy et al.		5	4 IE, 1 comp	5	3 education, 1 math 1 anthropology	U Oklahoma and some more	Qual	Achieving parity of the sexes at the undergraduate level: A study of success	2007	Core	Study women migration to engineering majors and retention	Analysis + solution

Foor et al. (2007)	1	Comp Science	2	Education	Oklahoma	Qual	” I wish that I belonged more in this whole engineering group:” Achieving individual diversity	2007	Periphery	What is the impact of STEM culture on individual diversity (the breadth of experience of a single individual)	Analysis + solution
Trenor et al.	1	Engineering	4	Education, psychology, Human dev	Clemson and U of Houston	Mixed	The relations of ethnicity to woman engineering students' educational experiences and college and career plans in an ethnically diverse learning environment	2008	Core	What are the experiences of women students in an ethnically diverse learning environment	Analysis + solution
Ohland et al.	4	3 Mechanical, 1 Mat science	2	Education	Purdue, Franklin, Stanford, Rose	Quant	Persistence, engagement, and migration in engineering programs	2008	Periphery	Is engagement a precursor to persistence	Analysis
Walden, and Foor	-	-	2	Education	U Oklahoma	Qual	“What's to keep you from dropping out?” Student Immigration into and within engineering	2008	Core	What impact did the decision of students to relocate to IE have on the achievement of sex parity in fall 2001 for IE at OU?	Analysis + solution

Cohen, and Deterding	-	-	2	Sociology, misc	Harvard, non-university	Quant	Widening the net: National estimates of gender disparities in engineering	2009	Core	What are the causes behind the severe underrepresentation of women in engineering?	Analysis + solution
Charyton and Merrill	1	first year	1	Psychology	Ohio state	Quan	Assessing general creativity and creative engineering design in first year engineering students	2009	Periphery	Assess creativity through the Creative Engineering Design Assessment (CEDA) in men and woman engineering students for comparison with men and women non-engineering students	Analysis
Mesa et al.	-	-	3	Education	U of Michigan	Quant	Measuring the impact of an individual course on students' success	2009	Periphery	Does enrollment in Applied Honors Calculus II have a positive causal impact on subsequent academic performance for engineering students	Analysis
Jones et al.	-	-	4	Engineering Education	Virginia Tech	Quant	An analysis of motivation constructs with first-year engineering students:	2010	Core	Do men and women differ with respect to their engineering expectancy-related beliefs, value-	Analysis

							Relationships among expectancies, values, achievement, and career plans			related beliefs, achievement, or career plans?	
Ohland et al.	1	Electrical	6	Education Sociology, Corporate	Purdue, San Diego, Rose Hulman	Quant	Race, gender, and measures of success in engineering education	2011	Core	Which measures of success are justifiable to women and minorities?	Analysis + solution
Min et al.	1	Chemical	4	Engg, Education, researcher	Korea, Purdue, U of Florida, East Carolina	Quant	Nonparametric survival analysis of the loss rate of undergraduate engineering students	2011	Core	Does the profile of risk of dropout differ among groups with different backgrounds?	Analysis
Lathem et al.	1	Civil	2	Education	Vermont	Mixed	The socially responsible engineer: Assessing student attitudes of roles and responsibilities	2011	Core	Are there differences in student attitudes related to graduating class, academic major (civil, civil / environmental, environmental), or gender?	Analysis
Litzler and Young	-	-	2	workforce dev, criminology	Washington, Arizona	Quant	Understanding the risk of attrition in undergraduate engineering:	2012	Core	How are individual characteristics, student experiences, and perceptions related to qualitative	Analysis

							Results from the project to assess climate in engineering			differences among students in their risk of attrition?	
Woodcock et al.			5	Psychology and engineering education	Purdue	Quant	Engineering students' beliefs about research: Sex differences, personality, and career plans	2012	Core	Will thing orientation be a significant predictor of intention to pursue a research career in engineering, and will be a stronger predictor of research career intentions for women than men?	Analysis
Martin et al.	-	-	3	Education, Psychology	Clemson, Virginia , Houston	Qual	The role of social capital in the experiences of Hispanic women engineering majors	2013	Core	For Hispanic women whose parents have limited educational attainment, how they manage social capital	Analysis + solution
Raelin et al.	3	2 Electrical, 1 Mech	2	Education, Admin	Northeastern, RIT, Wyoming, Virginia Tech	Quant	The gendered effect of cooperative education, contextual support, and self-efficacy on undergraduate retention	2014	Core	What is the effect on retention of demographic characteristics, cooperative education, contextual support, and three dimensions of self-efficacy?	Analysis + solution

Holloway et al.	-	-	4	Education, Administration	Purdue, TAMU, Ohio, Northwestern	Quant	Research-informed policy change: a retrospective on engineering admissions	2014	core	Is there statistically significant evidence of admission decision gender bias for engineering applicants?	Analysis + solution with evidence
Samuelson and Litzler	-	-	2	County office of education, workforce development director at university	U of Washington	Qual	Community cultural wealth: an assets-based approach to persistence of engineering students of color	2016	Core	What differences in community cultural wealth emerged at the intersection of race/ethnicity and gender?	Analysis + solution
Pawley et al.	-	-	3	Engineering education	Purdue	Review	Gender in engineering education research: a content analysis of research in JEE, 1998–2012	2016	Review	What are the dominant themes and patterns in the structure of gender research published in JEE?	Review

Ro and Knight	-	-	2	Education	Virginia Tech, Bowling Green State	Quant	Gender differences in learning outcomes from the college experiences of engineering students	2016	Core	How do curricular emphases, instructional approaches, and participation in co-curricular activities differently affect engineering learning outcomes by gender?	Analysis + solutions
Godwin et al.	2	Physics	2	Education	Purdue, Florida, TAMU	Quant	Identity, critical agency, and engineering: an affective model for predicting engineering as a career choice	2016	Core	To what extent do students' beliefs differ between men and women?	Analysis + solution
Atwood and Prez	1	Engineering	1	Psychology	Elizabeth Town	Quant	Creativity as a factor in persistence and academic achievement of engineering undergraduates	2016	Periphery	Can creativity predict engineering student persistence and achievement relative to demographics, academic aptitude, and personality? Are the predictors of persistence and achievement consistent throughout the UG program?	Analysis

Appendix B: Details of retention, graduation rates and academic performance of women engineering students wrt men engineering students (15)

Article	No of students	Student types	Women Six-year graduate rate	Women Retention	Academic Performance	Comments
Felder et al. (1995), A Longitudinal Study of Engineering Student Performance and Retention. III. Gender Differences in Student Performance and Attitudes	Total 108 (Men 77, Women 31)	Students from Chemical Engineering	Not Available (NA)	84% in the second year and 77% in the fourth year (for men the numbers were 92% and 81%, respectively	Fourth year overall GPA for women 3.08 and chemical GPA was 2.55 (For men 3.02 and 2.64)	No statistical significance
Moller-Wong and Eide (1997), 'An engineering student retention study'	Total 1151 Men 980 Women 171	Cohort of students, who enrolled for the first time in the College of Engineering at Iowa State University in the fall of 1990	Not Available (NA)	There was no difference in chances of retention based on gender (no mention of specific statistical para)	NA	The model estimates risk of attrition
Brainard and Carlin. (1998), 'A six-year longitudinal study of undergraduate women in engineering and science'	Women 672	Science and engineering students from University of Washington; 1991-1996	71% for 1991	Freshman women 80-97% and only sophomore women 82-89% (incremental)	NA	Individual students are tracked
Hawks and Spade (1998), Women and men engineering students: Anticipation of family and work roles	Total 249 Men 207 Women 42	All students enrolled in first year introduction to engineering course at a private university	NA	NA	Women 2.79 vs Men 2.70	

Johnson et al. (2004), 'Relationships between engineering student and faculty demographics and stakeholders working to affect change	Total 3773.8 K (‘000) Men 1894 K Women 1879 K	High school class of 1990 from all over the US	59% for women as against 70% for men	NA	NA	Includes only permanent residents and citizens
French et al. (2005), 'An examination of indicators of engineering students' success and persistence	Total 1,756 Men 1,425 approx. Women 331 approx.	Two cohorts of engineering UG students from a large US mid-western university, who enrolled during 2000 and 2001 academic years.	NA	No statistically significant effect of gender (odds ratio was 0.87 but p value was > 0.05)	Women have higher GPAs. P=0.05 R2=0.18	
Brown et al. (2005), 'Influence of African American engineering student perceptions of campus climate on graduation rates'	Students graduated between 1999-2001 – estimated to be more than 219 k	EWC (engineering workforce commission) national data. Average of engineering graduates of 1999, 2000, 2001 and average of freshmen enrollment of 1994,95, and 96.	75.4% for women vs 72.7% for men students.	NA	NA	Five year (and not six-year graduation rates)
Bernold et al. (2007), 'Understanding Our Students: A Longitudinal-Study of Success and Failure in Engineering with Implications for Increased Retention’	Total 1022 Men 846 Women 176	Incoming freshmen of 2002 of North Carolina State University (NCSU).	NA (The study period was limited to 3 years)	60% for both men and women at the end of three years	After the 1st semester: Women CGPA 3.24 as against men CGPA of 2.97; After the 2nd semester the difference was amplified to, 3.27 vs 2.89	Women scored significantly higher on Motivation and Time Management of LASSI; 26% women migrated to other courses

Ohland et al. (2008), 'Persistence, engagement, and migration in engineering programs	311 K total with 70K engg from Midfield; 73K total with 7K engg from NSSE; 160 engg students from APS No gender division	MIDFIELD (for persistence), NSSE (for engagement) and APS (Academic pathways) (for longitudinal experiences)	NA	No difference in retention of men and women (no mention of specific statistical para)	NA	First-time students (no transfer students)
Cohen and Deterding (2009), 'Widening the net: National estimates of gender disparities in engineering'	Total on average 390,913 per year Women on average 74,079 per year	The population of UG engineering programs at U.S. institutions—data cover academic years 1999–2000 through 2004–2005	NA	Four-year retention at freshmen level is 76% for women and 66% for men; At only sophomore levels 92% for women, and 82% for men.	NA	No differential attrition by gender. Disparities are due to inadequate enrollment of women. Excluded 28% programs, whose data was found to be unreliable
Jones et al. 2010. 'An Analysis of Motivation Constructs with First-Year Engineering Students: Relationships Among Expectancies, Values, Achievement, and Career Plans',	Total 363 Men 285 Women 78	Freshmen of a public mid Atlantic university	NA	NA	Men GPA was 3.12 as against women GPA was 2.97 (no statistical difference, though)	
Min, et al. (2011) 'Nonparametric survival analysis of the loss rate of undergraduate engineering students	Total 100,179 Men 79,397 Women 20,782	Nine southeast public universities (MIDFIELD), every student who attended from 1987 to 2004.	NA	Women 74% vs men 79.2%	NA	Includes only direct entry to first year engineering and looks at four-year time horizon

Ohland et al. (2011) 'Race, Gender, and Measures of Success in Engineering Education'	Total 73,154 Men 57,730 Women 15,424	Nine southeast public universities (MIDFIELD), every student who attended from 1987 to 2004.	53% for both men and women	60% for women and 61% for men	NA	First time in college students matriculating in engineering – excludes international students
Litzler and Young (2012), 'Understanding the risk of attrition in undergraduate engineering: Results from the project to assess climate in engineering	Total 10,366	21 schools that participated in PACE (Project to assess climate in engineering) survey	NA	Chances of women retention are statistically significantly lower.	NA	This is not based on actual attrition but based on students' intention
Atwood and Pretz (2016) 'Creativity as a Factor in Persistence and Academic Achievement of Engineering Undergraduates'	Total 85 Men 72 Women 13	A small, private, liberal arts college in the Mid-Atlantic region, 2011 and 2012 freshmen	NA	65% men and 69% women	NA	NA